THE CARBONIFEROUS FLORA OF PERU

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By W. J. JONGMANS

SYNOPSIS

A reconsideration of all the older records of Carboniferous plants from Peru, together with an examination of two important newer collections, fully confirms the Lower Carboniferous age of the flora. Several new species are described, including representatives of *Lepidodendropsis*, and the world distribution of this genus is reviewed.

INTRODUCTION

THE Carboniferous flora of Peru has been the subject of several papers. The principal flora is found on the peninsula of Paracas, which, as Berry (1922) points out, is largely made up of continental Carboniferous sediments and constitutes one of the very few deposits of this character in South America, and the only known occurrence of rocks of this age on the west coast of South America. Somewhat to the north-east of the peninsula there are other Carboniferous localities at Huanuco and in the neighbourhood of Cerro de Pasco. Up to the present little has been known of the flora of these localities. Gothan (1928) mentions *Rhacopteris circularis* Walton from Vichaicoto and S. Huanuco and *Knorria* and a *Calamites*-like specimen from Cachama, between Cerro de Pasco and Huanuco. Fortunately one of my former assistants, Dr. N. de Voogd, sent me a good collection from Carhuamayo. This collection and another from Paracas, put at my disposal by the Trustees of the British Museum, will be described in this paper.

REVIEW OF THE LITERATURE ON THE CARBONIFEROUS FLORA OF PERU

Almost at the same time as Berry, Seward (1922) described another set of plants from Paracas. According to these papers the outcrop at Paracas was first discovered by Fuchs (1900). Seward states: "The coal occurs in a series of greenish sandstones and grey and black carbonaceous shales, which have a north-easterly strike and dip about 25° south-eastwards. These are overlain unconformably on the neck of the peninsula by Tertiary sandstones and impure limestones. There is no definite stratigraphical evidence of the age of the coal-bearing beds, and the plants are therefore of special importance."

Fuchs (1900) recorded the following species: *Calamites suckowi* Bgt., *Sphenopteris hartlebeni* Dkr., *Baiera pluripartita* Schl., *Lepidodendron sternbergii* Bgt., *Sigillaria tessellata* Bgt., and *Stigmaria ficoides* Bgt.

Fuchs assigned the beds to the Upper Coal Measures, but his list is scarcely possible ; it contains common Carboniferous plants and Wealden species.

The Carboniferous flora was mentioned subsequently by Fuchs (1905), Dorca (1909), Marsters (1909) and Lisson (1917), without any reference to the Wealden species. Lisson's paper is the only one which contains any new facts on this flora ; he mentions *Lepidodendron rimosum* and *L. obovatum*, determined by Zeiller. The age is given as Westphalian. Some critical remarks will be given when treating the papers by Berry (1922) and Gothan (1928).

The next contribution to the Carboniferous flora of Peru was that by Steinmann (1911) who did not visit Paracas. He examined Fuchs' collection at the Cuerpo de Ingenieros de Minas in Lima, and listed the following forms for the Paracas flora : *Archaeocalamites radiatus*, *Lepidodendron* cf. *veltheimi*, *L.* cf. *volkmanni*, *Sphenopteris affinis* (*furcata*), *Rhodea filifera* and *Rhabdocarpus*.

The occurrence of these species would prove that the flora belongs to the Lower Carboniferous. It is interesting but somewhat remarkable that the plant-bearing Carboniferous should be of Lower Carboniferous age and the invertebrate-bearing Carboniferous of Upper Carboniferous age. Unfortunately no literature on the invertebrate fauna of the Peruvian Carboniferous is known to me, and so far as can be seen from the sections in Berry's papers (1922, 1922*a*) no invertebrate fauna had been met with on the peninsula of Paracas during his visit. Steinmann states that no marine fossils are known from Paracas. He visited a second Carboniferous locality near Huichaycota, some kilometres south of Huanuco on the Huallaga and found large stems of *Lepidodendron* and at different places many specimens which he records as *Rhacopteris inaequilatera* Goepp.

The introductory paper by Berry (1922*a*) contains no descriptions of the plants, but discusses the locality and the history of the knowledge of the flora up to that date and records the following :

Palmatopteris furcata (Bgt.), *Eremopteris whitei* Berry, *E. peruianus* Berry, *Calamites suckowi* Bgt., *Calamostachys* sp., *Lepidodendron rimosum* Sternb., *L. obovatum* Sternb., *Lepidophyllum* sp., *Lepidostrobus* sp., *Stigmaria* sp. and *Knorria* sp.

Berry visited Paracas and was able to make large collections ; his remarks on the locality and the mode of occurrence of the plants are very valuable. According to Berry the fossil plants occur at different horizons in the sections he examined, and " there is no chronologic change in the flora from top to bottom although fossil plants are more varied in the lowermost horizon. The materials are relatively coarse throughout and would seem to indicate rapid deposition." Over half of the section " is described as sandstone, which is often coarse and arkosic. Of the 273 feet described as shale 192 feet are distinctly sandy, so that less than 14% of the total thickness [of 585 feet], including the so-called coal seams, is fine-grained shale and even the coal contains much silty impurities. No underclays with rootlets, or upright stems were observed and the coaly layers have every appearance of having been formed of drift material " (Berry, 1922*a* : 191–192).

The flora is " extremely limited, although some of the elements are exceedingly common," especially the plants recorded as *Palmatopteris furcata*, *Eremopteris whitei*, *Calamites suckowi* and *Lepidodendron rimosum* (Berry, 1922*a* : 193). Berry

imagines " that the coarseness of the sediments and the apparent drifting of the material are mainly responsible for the absence of a more representative flora." Thus his collections contained " no traces of *Sigillaria, Cordaites, Sphenophyllum, Calamite* foliage, nor of any Neuropterids, Pecopterids, Alethopterids or Lonchopterids." He states that this feature of the flora is undoubtedly responsible for Steinmann's opinion (1911) that the Paracas flora is of Lower Carboniferous age. According to Berry the Paracas Carboniferous corresponds to the Westphalian stage.

In the same year Seward (1922) described a collection of plants from Paracas made by J. A. Douglas in 1911. Seward's flora contains *Sphenopteris* sp., *Lepidodendron* sp., *Sigillaria* (or *Lepidodendron*) sp., *Bothrodendron* sp., and Planta incertae sedis. His determinations are considered in detail below :

Sphenopteris sp. (Seward, 1922, pl. 13, figs. 1–3) is present in several fragments. " The branched axis is longitudinally striated and smooth ; the pinnules are more or less deltoid, deeply dissected, and the ultimate segments are obtuse or truncate." Seward compares it with *Sphenopteris furcata* Bgt., but in this species the segments are acute. He also compares it with *Eremopteris missouriensis* Lesquereux (White, 1899, pl. 5, figs. 1–3*a*) which does possess obtuse or truncate ultimate segments.

Several Lower Carboniferous species have pinnules which closely resemble the Peruvian specimens ; " the deeply dissected form of the lamina suggests comparison with pinnules of *Rhodea* and *Sphenopteridium*." Thus Nathorst (1920, pl. 1, figs. 11–13) figures as *Sphenopteridium norbergii* a plant which he compares with *Sphenopteris affinis* L. & H. ; the latter differs in its broader, thicker segments, and its stronger and more numerous nerves. It will later be shown that such comparison is important for the determination of the specimens and their age.

Lepidodendron sp. (Seward, 1922, pl. 13, figs. 4–6). The most important specimen (fig. 4) shows a branch with attached leaves. It is preserved on a carbonaceous sandstone and most of the details cannot be seen. However, it is clear that the " cushions " of the leaves are separated by undulate lines, that succeeding " cushions" are connected at the upper and lower ends, and that the surface is striated, though not in the deeply impressed portions of the cushions. Seward's fig. 5 shows some details on the leaf-cushion and the leaf-scar.

On pl. 13, fig. 6 Seward figures a *Lepidodendron* which he considers belongs to the same species as those illustrated in figs. 4, 5. The specimen is interesting as it shows the leaf-like organs very clearly. It somewhat resembles the figure published by Johnson (1913, pl. 41, fig. 3), but it is impossible to decide whether it is a portion of a cone or not. The long erect leaves are narrow and possess a distinct middle nerve. They are sharply pointed at their ends.

Sigillaria (or *Lepidodendron*) sp. (Seward, 1922, pl. 13, figs. 7, 8). " Pieces of a stem having contiguous leaf-cushions which bear leaf-scars agreeing both with some types of *Sigillaria* (e.g., *S. brardi* Bgt.) and with certain species of *Lepidodendron*. On the upper part of several leaf-cushions there is a small circular scar, presumably a ligule-pit. No vascular bundle scars or parichnos-scars can be detected." Seward compares his specimens with those named *S. brardi* from South Africa (Seward, 1897 : 326) and Brazil (White, 1908), which, however, probably do not belong to Brnogniart's species, nor even to the genus *Sigillaria*. He also com-

pares them with *S. mutans* Weiss & Sterzel (1893 : 84). It is very curious that Seward should compare his specimens with a true Stephanian species.

Bothrodendron (?) sp. (Seward, 1922, pl. 13, fig. 9 ; text-fig.). Seward describes two specimens under this heading " although it is by no means certain that the specimens shown in pl. xiii, fig. 9, and in the text-figure belong to the same species."

The specimen figured in pl. 13 shows " spirally-disposed and widely-separated, slightly prominent, transversely elongated, rhomboidal leaf-scars. " On the right-hand side, a thin carbonaceous layer probably represents the actual surface . . . On the partly decorticated surface there are discontinuous longitudinal ridges, and an irregular transverse wrinkling, but on the carbonized film no wrinkling is seen. There is no indication of any leaf-cushion, no ligular pit, and only a very faint suggestion in a few of the scars of a median vascular scar. The leaf-scars shown in the text-figure are rather more rounded and appear as slightly concave areas . . . In the small and widely-separated leaf-scars these fragments agree with *Bothrodendron, Pinakodendron,* and *Asolanus.* The form of the leaf-scar and the absence of a leaf-cushion are features more suggestive of *Bothrodendron.*"

The features mentioned by Seward are those which are shown on the stems and larger branches of *Bothrodendron,* whereas clear leaf-cushions and leaf-scars of a more lepidodendroid form occur on the smaller branches. It is known that the gap between these two extreme forms is filled by a whole series of transitions. It is somewhat tempting to consider the three forms described by Seward as smaller branches and stems of the same species.

The last plant mentioned by Seward (1922, pl. 13, fig. 10) has not been named. This is represented by crowded branched filaments which are " probably portions of pinnules of a fern-like plant, such as some of the Lower Carboniferous species referred to *Rhodea* or *Sphenopteridium.*"

Seward was at first inclined to regard his material as Upper Carboniferous in age. Dr. Kidston, however, regarded the palaeobotanical evidence as more favourable to a Lower Carboniferous horizon. After a re-examination of the specimens Seward modified his first opinion and agreed with Kidston. He remarks, however, that the plants are too imperfect to serve as trustworthy guides and that " further research is greatly to be desired, since the available data are inadequate as a basis for any positive statement."

Shortly after Seward's paper appeared, a fully illustrated account of the flora was published by Berry (1922). The determinations are discussed below :

Palmatopteris furcata (Bgt.) Berry, 1922, pl. 1, figs. 1–3.

The plant he named *Palmatopteris furcata* is exceedingly common in the Paracas deposits. He unites with it *Sphenopteris affinis* (Steinmann, 1911 : 50) and *Sphenopteris hartlebeni* (Fuchs, 1900 : 50). These records certainly represent the same species, but it is not certain that the specific determination given by Berry is right. He does not give a detailed description and an opinion can be based only on his figures (pl. 1, figs. 1–3). The species has since been renamed *Sphenopteris paracasica* by Gothan (1928 : 293).

Eremopteris peruianus and *E. whitei* (Berry, 1922, pls. 2–4).

Berry describes two new species of *Eremopteris*. He points out the difficulties of demarcation between *Eremopteris* (especially as used by American authors) and *Rhacopteris*. He compares his *Eremopteris peruianus* (pls. 2, 3) with *Rhacopteris transitionis* (Ett.) as recorded by Stur (1875, pl. 8, figs. 5–7) but there are other species of " *Anisopteris* " with which Berry's material may be compared. According to his description and figures the size and form of the pinnules are very variable and it is quite likely that more than one species of *Rhacopteris* occurs in the material.

According to Berry his second species, *Eremopteris whitei*, is identical with *E. elegans* Lesquereux (1880, pl. 53, fig. 7). Berry considers this species to be entirely different from the European *Rhacopteris elegans* (Ett.) and from *R.* (*Sphenopteris*) *asplenites* Gutb. These European species have nothing in common with the Peruvian material.

Berry describes his material as follows : " The pinnae are linear oblong, their divisions or pinnules are oblique, oblong or rhomboidal in form, narrowed to the somewhat decurrent base, deeply pinnately cut by narrow sinuses into cuneate divisions which are rounded or subcrenate distad. The venation is flabellate and largely immersed in the thick substance of the lamina."

Eremopteris whitei Berry cannot be a *Rhacopteris* (sensu stricto) or *Anisopteris*. It might possibly be compared with some species of *Sphenopteridium* as figured by different authors (e.g., Walton, 1926) but Berry's figure alone is not sufficient to identify it with *Eremopteris* or *Rhacopteris*, and until further data are available it can be named *Sphenopteris whitei* (Berry).

It must have been a rather robust plant as evidenced by the stout longitudinally striated rachises. The nervation, as far as can be seen in Berry's figure, does not seem to agree with that of *Rhacopteris* or *Anisopteris* nor with *Eremopteris elegans* as figured by Lesquereux (1880, pl. 53, fig. 7) ; it can much better be compared with that of *Sphenopteridium*. Another plant with which it may be compared is that figured by me (1940, pl. 4, fig. 9) from the Lower Carboniferous of Egypt and erroneously referred to *Rhodea* cf. *hochstetteri* Stur. Better material which I received later shows that the Egyptian specimens cannot belong to Stur's species, and I now have little doubt as to their identity with Berry's species.

Calamites suckowi Bgt. (Berry, 1922, pls. 5–7).

The plants figured by Berry as *Calamites suckowi* Bgt. are very fragmentary and broken. Most of them do not show a nodal line. The best example is seen in pl. 6. Here a nodal line is present on which the sharply pointed ribs are clearly alternating, so that a reference to *Asterocalamites* is precluded. The stems undoubtedly belong to *Calamites*, but the sharply pointed ribs show that it cannot be *C. suckowi* ; it looks more like *C. undulatus* Sternb.

Lepidodendron rimosum Sternb. and *L. obovatum* Bgt. (Berry, 1922, pl. 8 ; pl. 1, fig. 5).

The two species of *Lepidodendron*, *L. rimosum* Sternb. (plate 8) and *L. obovatum* Bgt. (pl. 1, fig. 5) described and figured by Berry agree with Zeiller's opinion on this

material (1917). It must be pointed out, however, that if Berry's figures agree with the originals there is a remarkable difference between pl. 1, fig. 5, and pl. 8, figs. 1, 2, on the one hand and pl. 8, fig. 3, on the other. Only in pl. 8, fig. 3, is a leaf-scar visible and it is likely that this drawing was not made from the figured specimens but included only to indicate Berry's conception of the species. His determinations will be discussed after reference to Gothan's paper.

Lepidostrobus sp. (Berry, 1922, pl. 1, fig. 4).

In his pl. 1, fig. 4, Berry figures a *Lepidostrobus*, described as " A characteristic *Lepidodendron* cone, too poor for identification or description." It is by no means certain that it is a *Lepidostrobus*. The cone is very similar to one figured by Johnson (1913, pl. 41, figs. 3, 4) as a cone or strobilus of *Bothrodendron kiltorkense*, but it does not show sufficient details to be certain of its identity.

Gothan (1928) described and figured some Carboniferous plants collected by Steinmann from Paracas and other localities to the north of this peninsula. Steinmann (1929) also dealt with this material. As many of the latter's figures are much clearer than those in Gothan's paper, the two can be considered together. A short review of the descriptions and discussions follows here :

Rhodea sp.

This is the form already recorded as *Rhodea filifera* by Steinmann (1911) and as Planta incertae sedis by Seward (1922). It is quite possibly a *Rhodea*, but specific determination is not possible.

Sphenopteris paracasica Gothan (1928, pl. 13, fig. 1) (including *Palmatopteris furcata* Berry, 1922, pl. 1, fig. 1 ; *Sphenopteris* sp. Seward, 1922, pl. 1, figs. 1, 2 ; Steinmann, 1929, text-fig. 30*a*, *b*).

Steinmann's figure is a copy of that in Gothan's paper, together with an enlargement of the pinnules. Seward, who notes the difference from *Palmatopteris furcata*, compares his material with *Rhodea* or *Sphenopteridium*, such as *S. norbergii* Nath., a species which its author compared with *Sphenopteris affinis*. Gothan compares it with *Adiantites bellidulus* Hr. (Nathorst, 1914, pl. 15, figs. 11–14). It is very probable that *Sphenopteris affinis* as recorded by Fuchs (1900) belongs to Gothan's species. Another species with which Gothan compares it is *Sphenopteris bodenbenderi* Kurtz (1921) from Carrizal, near Famatina, La Rioja. A comparison is also possible with some of the species described by Walton (1931, especially pl. 25, fig. 23) from the British Lower Carboniferous. The specimens known so far are too fragmentary for determination.

Nevertheless there is an important difference in the rachis as figured by Gothan and that figured by Seward. The former shows a rachis with a distinct middle line and no other ornamentation. Seward shows a rachis with a longitudinal striation. It is by no means certain that these two sets of specimens and those described by

Berry (no rachis and more penicillate pinnules) belong to the same species. There may be three different species, and so for the present it would be best to use Gothan's name *Sphenopteris paracasica* to indicate this type of plant.

Rhacopteris circularis Walton (Gothan, 1928, pl. 15, fig. 1).

Recorded from Vichaicoto, S. Huanuco, but not from Paracas, this is without doubt a *Rhacopteris*, though Gothan's specific determination may be questioned. Steinmann's fig. 29 includes a specimen which is comparable with that of Gothan's, together with some other figures of details of the leaves ; organs which he considers as aphlebia (D and E) ; and a fragment of a rachis (F), all found together with *R. circularis*. These figures, however, show details which are not completely identical with those in Gothan's figure.

The occurrence of *Rhacopteris* in these floras is very important. Berry (1922, pl. 2, figs. 1–3) described *Eremopteris peruianus* from Paracas, which almost certainly belongs to *Rhacopteris* and should be named *Rhacopteris peruianus* (Berry). It is possible, however, that it contains more than one species. The form of the pinnules is very variable, and as Gothan (1928 : 297) points out, it is probable that Berry's pl. 2, figs. 2, 3, especially fig. 3, belong to the plant which Gothan named *Rhacopteris circularis* Walton. If this is true the species has also been found in Paracas.

Berry's pl. 2, fig. 1 can be compared with *Rhacopteris petiolata* (Walton, 1926, pl. 16, fig. 10). For the present, however, Berry's name *Rhacopteris peruianus* must be retained, though new material may eventually show that it belongs to some previously described species.

Calamites peruvianus Gothan (1928, pl. 14, fig. 1).

Gothan illustrates some poorly preserved fragments of *Calamites* as a new species *Calamites peruvianus*, and considers Berry's *C. suckowi* as identical. As already pointed out (p. 195) these fragments belong to *Calamites* and not to *Mesocalamites* or *Asterocalamites*, since the ribs alternate regularly at the nodal lines. Their ends are not blunt as in *C. suckowi*, and Berry's figures show the sharp pointed ends of the ribs as in *C. undulatus*. Gothan supposes that these *Calamites* are only distantly related to the European species. However, the characters on which he bases this opinion (thin stems, with long and narrow internodes, without branch-scars or infra-nodal canal-traces) are characters which can be found in *C. undulatus* or which may be due to poor preservation and the fragmentary state of the specimens. There is no reason to create a new specific name for these fragments or to compare them with *Phyllotheca* or other genera of Equisetales. The specimen figured by Steinmann (1929, text-fig. 28) is even more fragmentary than those mentioned above. The only name which might be given is *Calamites* cf. *undulatus* Sternb., though the correct name should be *Calamites* sp. indet.

Lepidodendron peruvianum Gothan (1928, pl. 13, fig. 2).

This specimen is interesting as it does not show a leaf-scar. Gothan unites with this species *L. obovatum* and *L. rimosum* of Berry (1922, pl. 1, fig. 5 ; pl. 8, fig. 1

only). Berry's pl. 8, fig. 3 does not belong to this species, and most probably the drawing has nothing to do with the specimens figured on the same plate. In my opinion, however, Berry's pl. 8, fig. 2 should also be united with Gothan's species.

No leaf-scar is visible and the broad bands between the leaf-cushions point to *Lepidodendropsis*. The specimens may be compared with *Lepidodendropsis fenestrata* from the Lower Carboniferous of Egypt (Jongmans & Koopmans, 1940, pl. 2, figs. 4*a–c*). The only real difference is that those described by Berry and by Gothan are larger, and the leaf-cushions are broader and not so elongated. Gothan states that the surface of the bands which separate the cushions is smooth.

The figures published by Steinmann (1929, text-figs. 23A–D) are much better ; they show clearly that the material belongs to *Lepidodendropsis* and the similarity to the Egyptian material is still more striking. The Peruvian species should therefore be named *Lepidodendropsis peruviana* (Gothan) Jongmans.

Lepidodendron lissoni Steinmann (Gothan, 1928, pl. 14, fig. 2).

Another species of *Lepidodendron* figured by Gothan (1928) and by Steinmann (1929, text-fig. 24) is *L. lissoni* Steinmann. Gothan compares it with *L. spetsbergense* Nath. So far as one can judge from the figure the specimen is badly preserved and it may be an older stem of *Bothrodendron*.

Lepidodendron sp. (Gothan, 1928, pl. 15, fig. 3, left).

It is not possible to give an opinion on this specimen. There may be some connexion with Seward's pl. 13, figs. 7, 8 (*Sigillaria* or *Lepidodendron*), but this will be very difficult to prove. Gothan also refers to a branch of *Lepidodendron* which he compares with Seward's pl. 13, figs. 4, 6. He does not figure the specimen.

Asolanus (?) *minimus* Gothan (1928, pl. 15, figs. 2, 2*a*, ? 3, right).

The material is insufficient for a true understanding of the plant which Gothan named *Asolanus* (?) *minimus* ; it is not clear that it is an *Asolanus*. The ornamentation is more like that of *Bothrodendron* (or *Cyclostigma*) than of *Asolanus*.

? *Bothrodendron pacificum* Steinmann (Gothan, 1928, pl. 13, figs. 3, 3*a*).

Gothan compares his specimen with *Bothrodendron* sp. (Seward, 1922, pl. 13, fig. 9). It is very probable that Seward's figure represents a *Bothrodendron*– or *Cyclostigma*-like stem, but since all the leaf-scars in Gothan's figure are broken it is not possible to identify details of the scar. A ligule-scar could not be observed.

Fortunately Steinmann (1929, text-fig. 27) gives a much better picture of "*Bothrodendron*" *pacificum*. His figure is similar to Seward's fig. 4 and must belong to the same species. It follows that Steinmann's specific name *pacificum* can be used for Seward's (pl. 13, figs. 4, 7, 8), Gothan's (pl. 13, figs. 3, 3*a*) and Steinmann's figures. With the description of new material to be dealt with later in this paper, it will be shown that this species must be put into *Cyclostigma* and that Seward's fig. 9 is a bigger stem belonging to the same species. There is no trace of a ligule and therefore the material must belong to the eligulate group of the Lycopodiales.

Trachyphyton neglegibile Gothan (1928, pl. 14, figs. 3, 4).

It is difficult to give an opinion on Gothan's *Trachyphyton neglegibile*. He compares it with *Stigmariopsis*. No root-scars are visible, though these are often very indistinct in specimens of *Stigmariopsis*. Johnson (1914, pl. 15) figures some rhizomes of *Cyclostigma kiltorkense* which closely resemble Gothan's figure.

Gothan considers the flora to be of Lower Carboniferous age.

A further contribution to the Carboniferous flora of Paracas was published by Read (1938). It is based on material collected from the classic locality by H. Bassler in 1922. Bassler did not make a special exploration but picked only debris of rocks from a shallow shaft made by former collectors. Read records the following plants : *Sphenopteris "parasica"* Gothan (= *S. paracasica*), *Adiantites whitei* (*Berry*), *Adiantites peruianus* (Berry), *Adiantites bassleri* Read, *Rhacopteris ovata* (McCoy) Walkom, *Rhacopteris* cf. *cuneata* Walkom, *Aphlebia australis* Read, *Lepidodendron peruvianum* Gothan and *Calamites peruvianus* Gothan.

The type of flora described by Read is much the same as that in earlier publications. Some of his determinations are discussed below.

Adiantites whitei (Berry) and *A. peruianus* (Berry) Read, 1938, text-fig. 3.

It is not entirely clear why Read includes *Eremopteris whitei* and *E. peruianus* in *Adiantites*. In my opinion it would be better to unite *E. peruianus* with *Rhacopteris*. I am not sure that Read's fig. 3 is the same plant as Berry's *E. peruianus* and I am inclined to compare it with *Triphyllopteris collombiana* Sch. As to *Eremopteris whitei* I prefer to leave this in *Sphenopteris* until better and more complete specimens have been found.

Adiantites bassleri Read (1938, text-fig. 7).

Adiantites bassleri Read is known only from a few fragments. They show the outline but no venation. This plant possibly belongs to the species which will be described as *Triphyllopteris collombiana* (Sch.) (p. 214).

Rhacopteris ovata (McCoy) Walkom (Read, 1938, text-fig. 1).

I entirely agree with Read's determination of his text-fig. 1 as *Rhacopteris ovata* (McCoy). As will be seen later, new material from the De Voogd collection clearly shows that this form is represented in the flora. The specimen figured by Gothan (1928, pl. 15, fig. 1) as *R. circularis* Walton does not show the same characters but they are seen in Steinmann's text-fig. 29, in Berry's pl. 2, fig. 3 (? 2), and in the specimens figured in this paper.

It is possible that Gothan's figure should be separated from the others and compared with *R. circularis* Walton, or it may be that the margins in Gothan's specimen are not well preserved.

It is curious that Read states that *Rhacopteris ovata* is very common in Paracas. So far as is known from the older literature there is only one figure from Paracas (Berry's *E. peruianus*, pl. 2, fig. 3; fig. 2 is very doubtful) which may be compared

with *R. ovata*. Steinmann's specimens and Gothan's *R. circularis* Walton are from Vichaicoto, S. Huanuco.

Rhacopteris sp. cf. *R. cuneata* Walkom (Read, 1938, text-fig. 5).

A single fragment figured by Read as *Rhacopteris* sp. cf. *R. cuneata* may be correctly determined. Two fragments which resemble Read's figure will be described with the new material from Paracas belonging to the British Museum.

Aphlebia australis Read (1938, text-fig. 6).

This is a curious plant. It is a leafy, highly divided fragmentary organ ; the base is unknown. It is not possible to show a relationship with the other elements of the flora.

Lepidodendron peruvianum Gothan (Read, 1938, text-fig. 4).

Read's figure is not exactly like Gothan's pl. 13, fig. 2, and is more like Steinmann's figures. It is probable that this specimen belongs to *Lepidodendropsis*.

Calamites peruvianus Gothan.

Read mentions some specimens of *Calamites* which he unites with *C. peruvianus* Gothan. As already stated a specific name is unnecessary for these fragments.

In a paper on the fossil plants of the Neo-Paleozoic of Brazil, Read (1941 : 17) reviews the Mississippian floras of South America and gives a list of the Paracas flora according to his own observations. He records a similar flora collected from 10 km. N.E. of Garhuamayo, Peru. The collection is fragmentary and the following species are noted : *Rhacopteris ovata* (McCoy), *Adiantites bassleri* Read and *Lepidodendron peruvianum* Gothan.

He compares the flora with Lower Carboniferous floras from Argentina. Such a comparison could be made with success only after a revision of the floras of that country, since so many records from Argentina are in need of correction. It is clear, however, that the lower portion of the Carboniferous in Argentina has a similar *Rhacopteris*-flora, probably also with *Lepidodendropsis* to which almost certainly some of the *Lepidodendron* species listed from there may prove to belong.

Frenguelli (1943) was able to study some specimens of *Rhacopteris* from Carhuamayo, Peru, in the Museum of La Plata. (From this locality I received the specimens which are described in the last section of this paper). Frenguelli figures two specimens ; his pl. 3, fig. 1, is named *Rhacopteris circularis* Walton according to Gothan's determination and figure (1928, pl. 15, fig. 1), and his pl. 3, fig. 2 is named *R. ovata* and agrees with Steinmann's figures (1929, text-figs. 29A–C) and with Berry's pl. 2, fig. 3, and perhaps fig. 2 (1922). It is therefore probable that both species occur in the Lower Carboniferous of Peru.

In the same paper Frenguelli discusses specimens from Argentina. The specimen figured in his pl. 1 and the poorly preserved fragment in pl. 2, fig. 1, are from the Mine El Tupe, La Rioja, and those in pl. 4, figs. 1–3, are from Agua Salada, La Rioja ; these he names *Rhacopteris ovata* (McCoy). On pl. 4, fig. 4, he figures a

specimen also from Agua Salada which he names *R. circularis* Walton. The difference between the two species is rather slight. It may be that the crenulate border of *R. ovata* is different from the more or less entire margin of *R. circularis* and that the form of the segments is somewhat different from those of *R. circularis* which are more circular. At all events it is interesting that the Argentine species of *Rhacopteris* agree with the Peruvian ones.

Frenguelli (1943, pl. 2, fig. 3 ; pl. 4, fig. 4) also figures specimens which he calls *Calamites peruvianus* Gothan, but they are equally as indeterminable as all or at least most of the other figures published under this name. It is useless to name or figure such bad specimens.

In an earlier paper Frenguelli (1941) also compares Peruvian plants with the flora of Argentina, describing an old collection of fossil plants from Agua de los Jejenes, San Juan. This flora is said to contain : *Rhacopteris semicircularis* Lutz, *R. ovata* (McCoy), *Eremopteris* cf. *sanjuanina* Kurtz, *E.* cf. *whitei* Berry, *Rhabdocarpus* ? sp., *Lepidodendron* cf. *veltheimianum* Sternb., and *Bothrodendron australe* Feistm.

Rhacopteris semicircularis was first described by Lutz (1933 : 144) from the Culm of Geigen near Hof. He compares it with *R. circularis* Walton, but considers it to be different. Frenguelli's figures (pl. 1, fig. 1 ; text-fig. 1) show the specimen which he compares with this species. He also compares it with *Cardiopteridium*, a comparison which is quite possible.

It is a pity that he did not figure his *Rhacopteris ovata* which he compares with Steinmann's *Rhacopteris circularis* Walton.

The specimen which Frenguelli (1941, text-fig. 2) compares with *Eremopteris sanjuanina* Kurtz resembles somewhat the specimens described later in this paper as *Triphyllopteris*. A revision of the Argentine plants will possibly show more comparisons with the Peruvian flora.

This is also the case with *Eremopteris* cf. *whitei* Berry (Frenguelli, 1941, text-fig. 3). His determination may be right, and if so, this is the first time that Berry's species has been recorded outside Peru.

The figure (pl. 1, fig. 2) which Frenguelli compares with *Lepidodendron veltheimianum* is indeterminable. There is no reason to accept a relation with *Lepidodendron*. Here we have another example of the well-known fact that so many of the specimens identified or compared with this, itself rather doubtful, species are absolutely valueless. The same is true for the specimen figured in his pl. 1, fig. 3, which he names *Bothrodendron australe* Feistm. and that in pl. 2 which he calls *Lepidodendron* sp.

LIST OF THE CARBONIFEROUS FLORA OF PERU ACCORDING TO THE OLDER LITERATURE

As a preliminary result of this review of the older literature on the Carboniferous plants of Peru the following list of species is established :

Calamites cf. *undulatus* Sternb. (perhaps better as *Calamites* sp.). *C. suckowi* Bgt. (Berry, 1922) ; *C. peruvianus* Gothan (1928) ; ? *C. peruvianus* Read (1938) ; *C.* sp. Steinmann (1929, fig. 28).

Cyclostigma pacifica (Steinm.) Jongmans.

? *Bothrodendron pacificum* Steinmann (1929) ; *Lepidodendron* sp. Seward (1922) ; *Sigillaria* or *Lepidodendron* sp. Seward (1922) ; *Bothrodendron* sp. Seward (1922) ; " *Bothrodendron* " *pacificum* Gothan (1928).

" *Lepidodendron* " *lissoni* Steinmann (still doubtful).

Lepidodendropsis peruviana (Gothan) Jongmans.

Lepidodendron peruvianum Gothan (1928) ; Read (1938) ; *Lepidodendron obovatum* Bgt. (Berry, 1922) ; *Lepidodendron rimosum* Sternb. (Berry, 1922, excluding fig. 3).

Asolanus (?) *minimus* Gothan (still doubtful).

Rhodea sp. Steinmann.

Rhodea filifera Steinmann (1911) ; Planta incertae sedis Seward (1922).

Sphenopteris paracasica Gothan.

Palmatopteris furcata (Bgt.) Berry (1922) ; *Sphenopteris* sp. Seward (1922) ; *Sphenopteris* " *parasica* " Read (1938).

Sphenopteris whitei (Berry) Jongmans.

Eremopteris whitei Berry (1922) ; *Sphenopteris hartlebeni* Dkr. (Fuchs, 1900) ; ? *Sphenopteris affinis* (Steinmann, 1911) ; *Adiantites whitei* (Berry) Read (1938).

Rhacopteris cf. *circularis* Walton.

Rhacopteris circularis Walt. (Gothan, 1928) ; Frenguelli (1943).

Rhacopteris ovata (McCoy) Walkom.

Rhacopteris circularis Walt. Steinmann (1929) at least very probable for the crenulate margin ; *Eremopteris peruianus* Berry (1922, pl. 2, fig. 3 and probably fig. 2) ; *Rhacopteris ovata* (McCoy) Frenguelli (1943).

Rhacopteris cf. *R. cuneata* Walkom.

Rhacopteris cf. *cuneata* Walk. (Read, 1938).

Rhacopteris peruiana (Berry) Jongmans.

Eremopteris peruiana Berry (1922, pl. 2, fig. 1 only) [not *Adiantites peruianus* (Berry) Read (1938)].

cf. *Triphyllopteris collombiana* (Schimper).

Probably *Adiantites peruianus* (Read, 1938, text-fig. 3).
Possibly *Adiantites bassleri* Read (1938, text-fig. 7).

Aphlebia australia Read (1938).

Berry's *Lepidostrobus* (1922, pl. 1, fig. 4) resembles a cone of *Cyclostigma kiltorkense* figured by Johnson (1913, pl. 41, figs. 3, 4), and Gothan's *Trachyphyton neglegibile* is very much like Johnson's figures of the rhizome of the same plant.

The age of the flora is considered to be Lower Carboniferous by Steinmann, Seward (and Kidston), Gothan and Frenguelli. The only plant which could indicate a Namurian or Westphalian age is *Calamites* cf. *undulatus*. However, the specimens of *Calamites* recorded from Paracas are almost always indeterminable. Only in one case does it seem to resemble in some respects *Calamites undulatus*.

Berry (1931 : 295) considers the flora as of Westphalian age, and if the floral list given by him could be accepted, he certainly would be right. However, there are many mistakes and wrong identifications in his list, and the revised list of the specimens described by him definitely indicates a Lower Carboniferous flora.

The arguments of Gothan, Seward (Kidston), Steinmann, Read, and Frenguelli are so weighty that there can be little doubt as to the lower Carboniferous age of the flora. The description of the new collections will supply further evidence in favour of their arguments.

A NEW COLLECTION FROM PARACAS

Many years ago the Trustees of the British Museum, by the kind intermediance of Mr. W. N. Edwards, placed a new collection from this Peninsula at my disposal for study. The plants were collected by the late Professor J. W. Gregory, whose untimely death by drowning in a canoe accident in the rapids of the river Urubamba at the age of 68 occurred, during an expedition to Peru, on 2nd June, 1932.

Sphenopteris whitei (Berry) Jongmans

(Pl. 17, figs. 1–4)

? 1900. *Sphenopteris hartlebeni* Dunk. : Fuchs, p. 50.
? 1911. *Sphenopteris affinis* L. & H. : Steinmann, p. 50.
1922. *Eremopteris whitei* Berry, p. 20, pl. 4.
1938. *Adiantites whitei* (Berry) Read, p. 401.
? 1940. cf. *Rhodea hochstetteri* Stur : Jongmans & Koopmans, p. 228, pl. 4, fig. 9.
? 1941. *Eremopteris* cf. *whitei* Berry : Frenguelli, p. 470, text-fig. 3.

Occurrence. Paracas, Peru ; Agua de los Jejenes, Argentina ; Rhas Gharib, Egypt.

The collection includes a rather large number of specimens containing fragments of a plant which may be determined as *Sphenopteris whitei* (Berry). Some of them are figured here to prove their identity with those figured by Berry (1922) as *Ere-*

mopteris. There is no doubt about the agreement. The specimens do not show any remarkable or new details. The form of the pinnules agrees with Berry's figure. The venation, however, is not very clear. Amongst the numerous figures with which these fragments may be compared is *Rhodea hochstetteri* Stur (Jongmans & Koopmans, 1940, pl. 4, fig. 9) from the Lower Carboniferous of Egypt which is almost certainly identical with Berry's species. Better examples of the Egyptian material (collected more recently) will be described in a separate paper.

Other specimens belonging to this species are: V.25913, V.25934, V.25935, V.25937–39, V.25941–47.

Cyclostigma pacifica (Steinmann) Jongmans

(Pl. 17, figs. 5–7; Pl. 18, figs. 8–10; Pl. 19, figs. 11–14; Pl. 20, figs. 14$b_{2,3}$)

1922. *Lepidodendron* sp. Seward, p. 280, pl. 13, figs. 4–6.
1922. *Sigillaria* or *Lepidodendron* sp. Seward, p. 280, pl. 13, figs. 7, 8.
1922. *Bothrodendron* (?) sp. Seward, p. 281, pl. 13, fig. 9; text-fig.
1928. *Bothrodendron pacificum* Steinmann: Gothan, p. 296, pl. 13, figs. 3, 3*a*.
cf. 1928. *Lepidodendron* sp. Gothan, p. 295, pl. 15, fig. 3.
1929. *Bothrodendron pacificum* Steinmann, p. 31, text-fig. 27.

Small branches with very approximate prominent leaf-cushions with a somewhat elliptical leaf-scar without cicatricules. Ligule not visible. Distance between the cushions very variable, even on the same specimen. Cushions separated by vertical, sharp, undulated lines, so that there is always an open communication between the succeeding cushion-fields in the vertical row. Scars rounded in the upper half, lower half consisting of two lateral sides meeting in a sharp point. In older stems the distance between the scars is much greater, and the contours of the cushions disappear as the distance increases. Surface of older stems smooth or ornamented with undulating lines. Leaves long, narrow, and sharply pointed, with a distinct midrib (Seward, 1922, pl. 13, figs. 4, 6).

Description. The collection contains numerous branches and small and large stems. Several of the smaller stems belong to the same type and can be compared with those figured by Seward (1922, pl. 13, figs. 4, 7, 8) and by Steinmann (1929, text-fig. 27).

Unfortunately most of the specimens do not show the true leaf-scars as the prominent cushions are always broken at the tips. There are, however, strong indications that these stems bore somewhat elliptical scars. The lines separating the cushions are undulate but they are not always well marked, and in some cases the form of the cushions is irregular and crushed (see Seward, 1922, pl. 13, figs. 7, 8). This can be seen in Pl. 17, figs. 5, 6. Pl. 17, fig. 5*a*, is interesting as it shows the form of the leaf-scar very clearly, and this is also visible on specimen V.25929. Pl. 17, figs. 6, 7 and Pl. 18, figs. 8, 8*a*, show that the distance between the leaf-cushions is very variable, and this is even more so in Steinmann's text-fig. 27 which also shows that there are areas on the branches where the distance is much smaller than usual. Specimens V.25922, V.25924, V.25926 and V.25927 all belong to this type but are not so well preserved.

At first sight it seems somewhat peculiar that the leaf-cushions figured by Seward (1922, pl. 13, figs. 7, 8) belong to the same plant as his fig. 4. However, Pl. 17, fig. 5, and Pl. 18, fig.8, show that both types are present on the same specimen. It is possible that there are irregularities in the form of the cushions such as those seen in *Sigillaria* in regions where the large scars bearing the fructifications are found, or it may be that there is some difference between succeeding regions of stems and branches as is known from other species of *Sigillaria* in connexion with differences in the mode of growth (cf. Potonié, 1894). A similar difference is also present in *Bothrodendron leslii* Seward, in *Sigillaria mutans* Weiss, and in Steinmann's text-fig. 27.

One of the best specimens, with part of its counterpart, is shown in Pl. 18, figs. 9, 10. It shows stems on both sides. The branch in fig. 9 can be compared with Seward's fig. 4. In the photograph the cushions are not always distinctly visible, but the undulated lines between the vertical rows are well seen in several places.

The true scars are well preserved on the counterpart (Pl. 18, figs. 10, 10*a*). The separation of the rows of cushions is indicated by a very delicate undulated line, so that the leaf-cushions are situated in the centre of the broadest part which is narrowed up- and downward. There is always an open communication between the succeeding cushion-fields in the vertical rows. The real scar lies in a deep hollow of the impression (in reality an elevation). Over and under the scars and cushions there is a distinct smooth field. There is no special ornamentation on the rest of the cushions. These characters are very well seen in Pl. 17, fig. 5. No cicatricules or ligule are visible.

As already stated the space between the cushions and scars is variable. In Pl. 17, fig. 7, the space is considerable. At the same time the lines separating the vertical rows are less distinct and disappear, the characters of the cushions also decrease, and the more or less isolated scars are all that remains of the former structure. The form of the scar itself does not change very much ; it is somewhat more regularly elliptical. This is well seen in Pl. 19, figs. 11, 12. and in the counterpart specimen (V.25933). A very good example of this type is shown in Pl. 19, fig. 13 ; here the form of the leaf-scars is clearly visible. They have about the same form as those seen in Pl. 17, fig. 5 and Pl. 18, fig. 10. Another good example is given in Pl. 19, fig. 14, which can be compared with Seward's pl. 13, fig. 9.

That the isolated scars originally had the same form as that shown in Pl. 18, fig. 8 can be seen on the right of Pl. 19, fig. 11, where the elongated cushions and the undulating lines which separate them are visible.

The surface between the scars is smooth (or almost smooth) in the specimen figured by Seward (1922, pl. 13, fig. 9) and in that figured in Pl. 19, fig. 11. However, the specimens shown in Pl. 19, figs. 12, 14 are remarkable for a distinct ornamentation on the surface between the scars. This ornamentation consists of delicate longitudinal lines, a number of which converge towards the scars, and recalls that of *Bothrodendron*. As the ornamentation is not always visible it may be that its presence or absence is due to the layer which is preserved on the fossil. The ornamentation is somewhat similar to that figured by Gothan (1928, pl. 15, figs. 2*a*,

3) in his *Asolanus* (?) *minimus*. In the British Museum specimens the arrangement is visible in oblique lines and less distinctly in horizontal lines.

It is clear that, as in the case of the Westphalian species of *Bothrodendron*, *Cyclostigma kiltorkense*, and some species of *Lepidodendropsis*, the leaf-cushions on the young branches are very distinct, approximated, and more or less separated by dividing lines, so that they have a lepidodendroid aspect. On the lower parts of the branches and on the stems this lepidodendroid character decreases and disappears. The result is that the leaf-scars are placed on a rather smooth or delicately ornamented surface (Seward, 1922, pl. 13, fig. 9). This stage is seen in the specimen (with its counterpart) shown in Pl. 19, figs. 12, 14. An excellent specimen of this type is figured in Pl. 19, fig. 14*b*. One part of the specimen shows a not very distinct ornamentation between the scars, another part is almost smooth but shows the scars very well. The scars have the same form as those in Pl. 17, figs. 6, 7, but are much better preserved. The specimen represented in Pl. 19, fig. 11, is, in some respects, transitional between the extremes.

Rarely the leaves are still attached to the branches. The best examples are shown in Seward's pl. 13, figs. 4, 6; the leaves are long, narrow and sharply pointed, with a distinct midrib. The specimens show fragments of leaves rarely or not at all.

This species must belong to *Cyclostigma* and not to *Bothrodendron*, for the form of the leaf-cushions and their arrangement on the younger branches are entirely different from the latter and no ligule or cicatricules can be found. Steinmann's specific name *pacificum* must be retained, and therefore the correct name for these plants is *Cyclostigma pacifica* (Steinmann) Jongmans.

Specimens similar to those figured in Pl. 19, figs. 12, 14, with ornamentation on the surface between the leaf-scars, may be distinguished as var. *decorata*, although as stated above the presence or absence of this ornamentation may be due to preservation.

Regarding the determination of this plant as *Cyclostigma*, the "*Lepidostrobus*" figured by Berry (1922, pl. 1, fig. 4) and the peculiar specimen described and figured as *Trachyphyton neglegibile* by Gothan (1928, pl. 14, figs. 3, 4) may be important. The *Lepidostrobus* can be compared with the figures of cones of *Cyclostigma kiltorkense* in Johnson's paper (1913, pl. 14, figs. 3, 4) and Gothan's figures with those of the rhizome of this plant figured by the same author (Johnson, 1914, pls. 14, 15). It may yet be proved that these or similar organs belong to *Cyclostigma pacifica* or an allied species.

Genus ***LEPIDODENDROPSIS*** Lutz

Lepidodendropsis peruviana (Gothan) Jongmans

(Pl. 20, fig. 15)

1922. *Lepidodendron rimosum* Sternb.: Berry, p. 24, pl. 8, figs. 1, 2 only.
1922. *Lepidodendron obovatum* Brongn.: Berry, p. 26, pl. 1, fig. 5.
1928. *Lepidodendron peruvianum* Gothan, p. 294, pl. 13, fig. 2.
1929. *Lepidodendron peruvianum* Gothan: Steinmann, p. 30, text-fig. 23A–D.
1938. ? *Lepidodendron peruvianum* Gothan: Read, pp. 398, 402, text-fig. 4.

DESCRIPTION. As stated above the specimens identified as *Lepidodendron peruvianum* by Gothan (1928) and by Steinmann (1929) belong to *Lepidodendropsis*. Three examples of this species are in the British Museum collection (V.25911, V.25912 and V.25931). The best specimen is that seen in Pl. 20, fig. 15. Form and arrangement of the cushions agree with those figured by Gothan (1928, pl. 13, fig. 2) and by Steinmann (1929, text-fig. 23). There is, however, a slight difference. According to their figures and descriptions the surface of the bands separating the leaf-cushions is smooth. This is not the case in the new specimens, where some rather coarse longitudinal or almost longitudinal lines are present. This difference may be essential or may be due to the state of preservation. At all events, the comparison made between this species and the Egyptian *Lepidodendropsis fenestrata* Jongm. & Koopm. increases in probability.

Lepidodendropsis ("Lepidodendron") lissoni (Steinmann) Jongmans

(Pl. 20, fig. 16)

1928. *Lepidodendron lissoni* Steinmann : Gothan, p. 295, pl. 14, fig. 2.
1929. *Lepidodendron lissoni* Steinmann, p. 31, text-fig. 24.

DESCRIPTION. The British Museum collection contains a specimen (V.25932) which may belong to the same species as that figured by Gothan (1928) and by Steinmann (1929). Gothan compares the species with *Lepidodendron spetsbergense* Nath. The specimen is distinguished by the peculiar field under the scars. It may be that such fields are the remains of lepidodendroid cushions, and it is probable that this plant belongs to *Lepidodendropsis*, in which case it might be compared with *Lepidodendropsis cyclostigmatoides* Jongmans, Gothan & Darrah (1937, pl. 50, fig. 28). Since no true *Lepidodendron* has been found in the flora of Paracas it is safer to use the name *Lepidodendropsis* ? *lissoni* (Steinmann) Jongmans. Better specimens are necessary before a final decision is possible.

? ***Lepidodendropsis*** sp.

(Pl. 20, fig. 17)

This remarkable specimen (V.25915) shows two large branches or stems, at least 7–8 cm. broad. They are covered with cushions very similar to those of *Lepidodendropsis*. No real leaf-scar is visible. One of the stems shows fragments of the leaves attached to it, and it is clear that in this species the leaves were very persistent. Although it is almost certain that the specimen belongs to an undescribed species, the details are too poorly preserved for specific determination.

Rhacopteris cf. ***cuneata*** (Walkom)

(Pl. 20, fig. 18)

1938. *Rhacopteris* cf. *cuneata* (Walkom) : Read, p. 401, text-fig. 5.

Two small specimens (counterparts, V.25948) can be compared with *Rhacopteris* sp. cf. *R. cuneata* (Walkom) figured by Read (1938, text-fig. 5). The specimens are

illustrated in Pl. 20, figs. 18, 18*a*, 18a_1. The occurrence of a very small fragment of *Rhacopteris ovata*, which can be seen at the top left corner of Pl. 20, fig. 18*a*, is interesting. The only previously recorded specimen of *Rhacopteris ovata* from Paracas is that figured by Berry (1922, pl. 2, figs. 2, 3) as *Eremopteris peruviana*. Better examples of this species are known from Vichaicoto, S. of Huanuco, Peru (Steinmann, 1929, text-fig. 29) and from Peru and Argentina (Frenguelli, 1943, pls. 1–4).

It is curious that the present collection does not contain specimens of *Rhacopteris circularis* nor, except for the fragment referred to, of *Rhacopteris ovata* which must, however, belong to the more common elements of the Peruvian flora.

Asolanus (?) *minimus* Gothan

1928. *Asolanus* (?) *minimus* Gothan, p. 295, pl. 15, figs. 2, 2*a*, ? 3 right.

The collection contains two small fragments (V.25909 and V.25910) which may be compared with Gothan's species. Unfortunately the preservation is too bad for the specimens to be figured.

From the flora represented in the British Museum collection it follows that although the number of species is relatively small, it provides more and better evidence regarding several of these species.

The full list of the flora so far known from the Paracas Peninsula contains the following species:

Calamites sp. (cf. *undulatus* Sternb.).
Cyclostigma pacifica (Steinm.).
Lepidodendropsis peruviana (Gothan).
Lepidodendropsis sp.
Lepidodendropsis ? *lissoni* (Steinm.).
Asolanus ? *minimus* Gothan.
Rhodea sp.
Sphenopteris paracasica Gothan.
Sphenopteris whitei (Berry).
Rhacopteris ovata (McCoy).
Rhacopteris ? *circularis* Walton.
cf. *Rhacopteris cuneata* (Walkom).
cf. *Triphyllopteris collombiana* (Sch.)
Adiantites bassleri Read (*Triphyllopteris*).
Aphlebia australis Read.
" *Lepidostrobus* " sp. Berry (? *Cyclostigma*).
Trachyphyton neglegibile Gothan (? *Stigmaria*, ? *Cyclostigma*).

The British Museum collection provides further proof that the flora of Paracas must be of Lower Carboniferous age. The aspect of the flora is similar to that of the Lower Carboniferous of Egypt and of the Pocono in U.S.A., although there are

minor differences ; thus *Rhacopteris* of the Peruvian type is not yet known from Egypt or the Pocono formation.

FLORA OF CARHUAMAYO

Dr. De Voogd, one of my former assistants, sent me a good collection of plants from the neighbourhood of Cerro de Pasco at Carhuamayo. With the exception of the specimens of *Rhacopteris* figured by Frenguelli (1943) no descriptions or figures of plants from this locality have so far been published. Read (1941 : 17) mentions a florule from this locality containing *Rhacopteris ovata* (McCoy), *Adiantites bassleri* Read (possibly identical with his figure (1938 : 402, text-fig. 7) from Paracas, belonging to *Triphyllopteris*), and *Lepidodendron peruvianum* Gothan (erroneously ascribed by the author to Berry & Read) which probably belongs to *Lepidodendropsis peruviana* (Gothan).

The new collection is important for the remarkable forms of *Lepidodendropsis* and the very good specimens of *Rhacopteris* and *Triphyllopteris*.

Lepidodendropsis de voogdi n. sp.

(Pl. 21 ; Pl. 22, figs. 24–27 ; Pl. 25, fig. 32 ?)

Diagnosis. Stems with leaves, sometimes with sporangia. Stems with scars of *Lepidodendropsis* type, covered by the basal parts of the leaves. Scars numerous. Distance between scars small. Leaves spreading, 3 cm. or more long, up to 5 mm. broad, acuminate, with a distinct middle nerve. Sporangia, containing megaspores, visible in the axils of the leaves.

Description. Pl. 21, fig. 19 shows the axis and leaves (or sporophylls) of a specimen which make a somewhat lepidodendraceous impression. The axis is very broad. The scars, badly preserved, are placed in obliquely ascending lines. The horizontal and vertical arrangements are both distinct, but the oblique arrangement is most striking. Numerous leaves (or sporophylls) are connected with the axis. They are 3 cm. or more long and up to 5 mm. broad, acuminate, with a distinct middle nerve. The lower (sporangium-bearing) part is rather short, about 5 mm. long, and increases in breadth towards the implantation of the axis. This basal part is not very clearly separated from the rest. The leaves are spreading and very crowded. They resemble a *Lepidophyllum* of the *lanceolatum* type.

A second specimen (Pl. 21, fig. 20) is much longer. It shows the sporophylls, but the form of these is not so well seen. The most interesting part of this specimen is where the large, *Lepidostrobus*-like sporangia are visible on the outer left and right sides. They are 3–4 mm. broad and about 2 mm. high. Their size agrees with the basal part of the sporophylls in the first specimen. The specimen shows that the sporangium-bearing part of the sporophyll is almost horizontal and that the free part is abruptly erect.

The form of the scars on the broad axis is not visible, probably due to fragments of the sporophylls which more or less cover them. As far as can be seen, they appear to be almost elliptical.

A specific determination of the strobilus, or perhaps sporophyll bearing branches is of considerable importance. In this respect a specimen with similar leaves, but with no sporangia present (Pl. 21, figs. 21, 21*a*) is of value. It shows two leaf-bearing branches, one of which, the branch on the left (Pl. 21, fig. 21*a*), shows scars which agree completely with the small scars of *Lepidodendropsis*.

Another branch shows a bifurcation (Pl. 21, figs. 22, 22*a*). The scars are oval elliptical and are about the same size as those shown in Pl. 21, figs. 21, 21*a*. The leaves are broken. In the axils of the leaves are the remains of sporangia which contain megaspores.

This specimen is clearly a fructification which does not form a true strobilus and which agrees in this respect with *Lepidodendropsis vandergrachtii*. The latter species differs, however, as in *Pinakodendron*, in the absence of lepidodendroid sporangia which are present in the Peruvian material. On the back of this specimen two fragments of branches are visible both with long leaves attached (Pl. 21, fig. 23). One, on the left, without, the other, on the right, probably with sporangia and spores.

Another specimen (Pl. 22, fig. 24) shows two fragments of branches, both with well-preserved leaves and probably sporangia and spores. The leaves show the general form of those in Pl. 21, fig. 19, but they appear to be somewhat narrower. Pl. 22, fig. 25, shows a narrow branch with very long leaves of the same type. There is no trace of sporangia or spores.

A somewhat curious specimen (Pl. 22, fig. 27) shows leaves only without a trace of the branches or stems. The specimen figured in Pl. 22, fig. 26 shows isolated leaves which are unusually narrow.

This plant undoubtedly belongs to *Lepidodendropsis*. It is here named *Lepidodendropsis de voogdi* after Dr. De Voogd who collected the material for me.

Lepidodendropsis cf. ***de voogdi*** Jongmans

(Pl. 25, fig. 32)

This specimen has no leaf-scar and the " cushion " is of the *Lepidodendropsis* type. It is possible that it belongs to one of the other species, but it may be different. It can be compared with *Lepidodendropsis de voogdi* (Pl. 21, fig. 21) which shows the same type of leaf-bases.

Lepidodendropsis steinmanni n. sp.

(Pl. 22, figs. 28*a*, *d*; Pl. 23, figs. 28*b*, *c*; ? Pl. 24, fig. 31)

Diagnosis. Large stem, more than 3·5 cm. broad, covered by small " cushions." Horizontal distance between two cushions about 0·8 cm., oblique distance 4–5 mm. Vertical distance variable. Cushions occasionally more crowded, very small and not very distinct, indicated by smooth, almost triangular spaces (probably representing the basal parts of the leaves attached at the top of the " cushions "). Leaves attached at the " cushions " with their full base ; on leaving the stem they are first directed downwards and then obliquely erect.

DESCRIPTION. A second species of *Lepidodendropsis* is represented by a large stem with counterpart. Between these two parts a fragment of the pith cast is present (Pl. 22, fig. 28*d*). The stem is rather broad, somewhat more than 3·5 cm. wide and covered by small " cushions " (Pl. 22, fig. 28*a*) arranged in ascending lines. The arrangement in horizontal lines is not very distinct. The horizontal distance between two cushions is about 0·8 cm., the oblique distance 4–5 mm. The distance between the scars is not always the same. In at least two places they are more crowded, as in *Lepidodendropsis vandergrachtii* from the Pocono. The best "cushions " can be seen at the top of the figure. They are very small and agree generally with those of *Lepidodendropsis* (Pl. 23, fig. 28*c*) ; a cushion is indicated by a smooth, almost triangular space. A leaf-trace is not visible, and the upper part of the " cushion " bends into the rock over the upper limit of the " cushion." The space between the cushions is finely granulated (chagrinate) and almost smooth (Pl. 23, fig. 28*c*).

The pith-cast is covered by a thin coal-layer which is somewhat more distinctly chagrinate than the impressions. This delicate ornamentation is also visible on the actual surface of the pith-cast (Pl. 22, fig. 28*d*).

The stem bears narrow leaves which are specially well seen on the upper part. The leaves are directed downwards for about 4 mm. as they leave the stem, but from there they are abruptly erect.

This species agrees rather well with *Cyclostigma ungeri* Jongmans, Gothan & Darrah (1937, pl 57, figs. 45, 45*a*). Here too the horizontal lines in the arrangement of the cushions are much less developed than the very distinct oblique lines, and the surface bears a very delicate ornamentation. This ornamentation is different, however, and the cushions are larger, not so punctiform, and the horizontal and vertical distances between the cushions are much greater.

The leaf-cushions of the Peruvian specimens do not agree with those of *Cyclostigma* and more closely resemble those of *Lepidodendropsis*. A true leaf-scar is not visible.

In the description of *Cyclostigma ungeri* it was pointed out that it was only provisionally compared with that genus. It probably belongs to *Lepidodendropsis*.

The new name *Lepidodendropsis steinmanni* is provisionally proposed for the Peruvian species.

Lepidodendropsis cf. ***steinmanni*** Jongmans

(Pl. 24, fig. 31)

In this specimen the leaf-cushions are similar in form to those of *Lepidodendropsis steinmanni* but they are much larger. It may be an older stem of this species and is named *Lepidodendropsis* cf. *steinmanni* accordingly.

Cyclostigma pacifica (Steinmann)

(Pl. 24, fig. 30)

A small specimen belonging to this species may be compared with those figured by Seward (1922, pl. 13, figs. 4, 6). It shows the shape of the cushions and also

fragments of the leaves. It is remarkable that this is the only specimen in the new collection which undoubtedly belongs to this species.

Cyclostigma cf. *pacifica* (Steinmann) var.

(Pl. 23, fig. 29*a*; Pl. 24, fig. 29*b*, *c*)

A plant which probably belongs to *Cyclostigma* is represented by a small fragment found in the same block as the specimen figured in Pl. 22, fig. 28. It consists of the impression of the upper and lower sides of the stem and a part of the pith-cast (Pl. 23, fig. 29*a*; Pl. 24, fig. 29*b*, are from the upper and lower surfaces, Pl. 24, fig. 29*c*, from the pith-cast).

The leaf-cushions have the same form as those found in *Cyclostigma pacifica*. The only difference is that they are much more flattened, and are not so prominent as in most of the specimens of that species. The surface of the cushions is not smooth. There are also fragments of leaves which are shown in Pl. 24, fig. 29*b*, *c*.

A detailed description seems unnecessary since the figures show the details rather well. The lines separating the cushions are delicate but sharp and are well seen in several places (Pl. 23, fig. 29*a*, left side; Pl. 24, fig. 29*b*). The leaf-scars are placed in the centre of the cushions. The surface is finely chagrinate.

It is very probable that this plant is specifically identical with *Cyclostigma pacifica* and it is therefore described as *C.* cf. *pacifica* var. until more complete specimens are available for study.

Rhacopteris ovata (McCoy) Walkom

(Pl. 25, figs. 33–37; Pl. 26, fig. 45)

1922. *Eremopteris peruianus* Berry, p. 19, pl. 2, fig. 3, ? fig. 2.
1929. ?*Rhacopteris circularis* Walton: Steinmann, p. 33, text-fig. 29 A–C.
1938. *Rhacopteris ovata* (McCoy): Read, p. 401, text-fig. 1.
1943. *Rhacopteris ovata* (McCoy): Frenguelli, pp. 14, 22, pl. 1; pl. 2, fig. 1; pl. 4, figs. 1–3 (Argentina); Pl. 3, fig. 2 (Carhuamayo).

Occurrence. Paracas; Vichaicoto, S. Huanuco and Carhuamayo, Peru. El Tupe, La Rioja, Argentina.

As in Vichaicoto, S. of Huanuco, specimens of *Rhacopteris* of different sizes are very common at this locality. Some of them are excellently preserved.

In many cases it is not easy to distinguish the two species *Rhacopteris circularis* and *Rhacopteris ovata*. The chief differences are the margins and the form of the pinnules. In typical specimens the margins of *Rhacopteris ovata* are crenulate and the form of the pinnules is distinctly asymmetric and not circular. However, in Walton's description of *Rhacopteris circularis* (1926 : 208) he states " Margin of pinnules entire, more rarely crenulate or lobed. Pinnules circular to semi-flabelliform. There is a tendency to asymmetry in the higher pinnules on the frond." It is possible that in most cases the smaller specimens show the characters of *R. circularis* and the larger ones those of *R. ovata*. Frenguelli (1943) figures specimens

which he ascribes to both species. His figures of *R. ovata* (pl. 1 ; pl. 3, fig. 2 ; pl. 4, figs. 1–3, especially fig. 2) show the characters of *R. ovata* very well, with crenulate, asymmetric large pinnules.

Frenguelli's pl. 3, fig. 1, shows rounded pinnules and no crenulation, whereas the specimen in pl. 4, fig. 4, shows pinnules even more rounded and slightly asymmetric, also without crenulation. In some respects this latter specimen is transitional between the two extreme types.

Berry's figures (1922, pl. 2, fig. 3 and possibly fig. 2) show the characters of *R. ovata*. Steinmann's figures (1929, text-figs. 29*a–c*) can also be identified with this species, but Gothan's figure (1928, pl. 15, fig. 1) is somewhat doubtful ; most of the pinnules are incomplete and it is possible that they may have been more rounded. As far as can be seen there is no crenulation. The specimen figured by Read (1938, text-fig. 1) also shows the characters of *R. ovata*.

Amongst the figures of *R. ovata* in the older literature is an interesting specimen figured by Dun (1905, pl. 23). This specimen is very long, the lower part of the pinna shows the large, crenulate and more or less asymmetric pinnules typical of *R. ovata*, whereas the upper part of the pinna shows much smaller symmetric pinnules with distinctly circular upper margins. Similar small pinnules are also represented in Dun's pl. 22, fig. 3.

Several of the specimens figured by Feistmantel (1890) do not show the crenulated margin and some of them are more or less circular (e.g., specimens in pl. 4), whereas others agree more closely with *R. ovata* (pl. 5, fig. 2 ; pl. 8 ; pl. 9, especially fig. 2). Some crenulation is indicated in his pl. 7, fig. 1.

Walton's figures of *R. circularis* generally show a uniform character in the shape of the pinnules, which is never or very rarely found in specimens of *R. ovata*. Therefore I am inclined to consider most of the Peruvian specimens as belonging to *R. ovata*.

In most of the specimens the margins of the pinnules are not preserved or have been broken off or hidden in the rock. This is the case with much of the present material, although, on most of these specimens, the crenulation is visible somewhere. The shape of the pinnules differs considerably. An extreme type is the large specimen shown in Pl. 25, fig. 33. A number of specimens (Pl. 25, figs. 34–37) show pinnules of different sizes, and some of them show the venation quite well.

Rhacopteris cf. ***circularis*** Walton

(Pl. 25, fig. 38 ; Pl. 26, fig. 39)

1928. *Rhacopteris circularis* Walton : Gothan, p. 293, pl. 15, fig. 1.
1943. *Rhacopteris circularis* Walton : Frenguelli, pp. 22, 41, pl. 3, fig. 1 ; pl. 4, fig. 4.

Occurrence. Carhuamayo and Vichaicoto, Peru. Agua Salada, La Rioja, Argentina.

A fine specimen of *Rhacopteris* is represented in Pl. 25, fig. 38. Here most of the pinnules have more or less rounded margins and their dimensions are very variable. It is interesting to note that the pinnules show a distinct footstalk, as in Walton's

figures of *Rhacopteris circularis*. If *R. circularis* is present in the Peruvian flora, then this specimen may be considered to belong to it. Feistmantel's figured specimens with margins and pinnules typical of *Rhacopteris ovata* do not possess such a distinct leaf stalk. It is possible that the specimen figured in Pl. 26, fig. 39, which has rather distinct leaf stalks also belongs to *Rhacopteris circularis* Walton.

Genus ***TRIPHYLLOPTERIS*** Schimper

This genus is well represented in the collection from Carhuamayo. Three forms can be distinguished and they may belong to different species.

Triphyllopteris collombiana (Schimper)

(Pl. 26, figs. 40–42)

? 1938. *Adiantites peruianus* (Berry) Read, p. 401, text-fig. 3.
? 1938. *Adiantites bassleri* Read, p. 399, text-fig. 7.
1941. cf. *Eremopteris* cf. *sanjuanina* Kurtz : Frenguelli, p. 468, text-fig. 2.

Occurrence. Paracas and Carhuamayo, Peru ; Agua de los Jejenes, Argentina.

A rather large form is represented by several specimens of which Pl. 26, figs. 40–42, are typical examples. These specimens resemble *Triphyllopteris collombiana* as figured by Schimper (1862, pl. 25, figs. 8–10, *Cyclopteris*) from Burbach. The nervation is well shown in Pl. 26, fig. 42.

It is possible that the specimens figured as *Adiantites peruianus* and *A. bassleri* by Read (1938) belong to this species.

Triphyllopteris lescuriana (Meek)

(Pl. 26, figs. 43–45)

The specimens referred to this species are much smaller and the leaves are more divided than in *Triphyllopteris collombiana*. In every case the pinnules are divided in a way which is typical for this genus.

The specimens represented in Pl. 26, figs. 43, 44, have elongated, acuminate divisions of the individual segments. Fig. 43 is part of the top of a leaf and shows the division of the segments very clearly. As far as can be seen the venation agrees with that described for *Triphyllopteris*.

It is very probable that the specimen figured in Pl. 26, fig. 45 also belongs to this species, although the divisions of the pinnules are not so sharply acuminated. Good examples of *Rhacopteris ovata* occur on this specimen, one with large, and one with small pinnules.

These specimens agree rather well with *Triphyllopteris lescuriana* (Meek) as figured by Jongmans, Gothan & Darrah (1937, pl. 44, figs. 7, 8) and by Lesquereux (1880, pl. 50, fig. 6).

? *Triphyllopteris peruviana* n. sp.

(Pl. 26, fig. 46)

DIAGNOSIS. Dimensions much smaller than in *T. lescuriana* and the division of the leaf much denser. Pinnules divided in five lobes, the top lobe elongate, the side lobes rounded and much shorter than in *T. lescuriana.*

DESCRIPTION. The third form is represented by one good specimen (Pl. 26, fig. 46) and one fragment. The dimensions are much smaller and the division of the leaf is much denser. The division of the pinnules into three lobes is not so regular. In most cases there are five lobes, the top lobe being elongate, the side lobes more rounded and much shorter. It is not certain that this specimen really belongs to *Triphyllopteris* and it is therefore provisionally named ? *Triphyllopteris peruviana.* More and better material is necessary before it can be attributed to this genus with certainty.

CONCLUSION

The flora of Carhuamayo contains :

Lepidodendropsis de voogdi Jongmans.
Lepidodendropsis cf. *de voogdi* Jongmans.
Lepidodendropsis steinmanni Jongmans.
Lepidodendropsis cf. *steinmanni* Jongmans.
Lepidodendropsis sp.
Cyclostigma pacifica (Steinmann) Jongmans.
Cyclostigma cf. *pacifica* (Steinmann).
Rhacopteris ovata (McCoy).
Rhacopteris cf. *circularis* Walton.
Triphyllopteris collombiana (Schimper).
Triphyllopteris lescuriana (Meek).
? *Triphyllopteris peruviana* Jongmans.

It is clear that this flora, as was to be expected, is of Mississippian age.

THE DISTRIBUTION OF *LEPIDODENDROPSIS*

It is clear that the age of the Peruvian Carboniferous floras is Mississippian, and this was the opinion of most of the earlier authors. Berry, however, accepted a Pennyslvanian age for Paracas, but it has since been proved, in particular by Gothan, that the determinations upon which Berry based his conclusion were not correct. The records described in this paper fully agree with a Mississippian age.

As previously stated the Peruvian flora is very similar to that of the Pocono in the United States. A number of species of *Lepidodendropsis* were described from the Pocono (Jongmans, Gothan & Darrah, 1937) some of which resemble the type species *Lepidodendropsis hirmeri* Lutz. Other species such as *L. vandergrachti* have quite a different habit and are more like *Sigillaria.* The fructification of this species is not a strobilus but, as in *Pinakodendron*, the spores are found at the base of small

sporophylls on young twigs. A similar fructification is recorded for the Peruvian *Lepidodendropsis de voogdi* Jongmans. Other important elements of the Pocono flora are some species of *Triphyllopteris*. *Rhacopteris* was not present in the Pocono collections examined.

Trochophyllum breviinternodium (Arnold, 1933; renamed *Prolepidodendron*, Arnold, 1939, pl. 1, fig. 2) very much resembles *Lepidodendropsis*. The only difference is in the form of the leaves, with their broad, flattened, upper ends. It is possible that this species is in some way a transition with *Protolepidodendron* Krejci which is certainly related to *Lepidodendropsis* but distinguished by the leaves which in their upper parts are divided into two. If the leaves are not preserved, or the division of the leaves is not visible, it is almost impossible to distinguish the stems of *Protolepidodendron scharyanum*, as figured by several authors, from those of *Lepidodendropsis*.

Arnold's specimens are from the Upper Devonian (Oswayo sandstone), near Port Allegany, McKean County, Pennsylvania, which was originally placed in the Pocono (Arnold, 1933).

Prolepidodendron breviinternodium (Arnold) has been found associated with *Archaeopteris* cf. *roemeriana*, *Rhacopteris* sp. (cf. *R. circularis* Walton from the Teilia beds), and fragments of *Callixylon*.

Colpodexylon Banks (1944) is another related genus with dichotomous or three-forked leaves.

Lutz (1933) described *Lepidodendropsis* as a new genus from the Lower Carboniferous of Geigen near Hof, Bavaria. In that flora *L. hirmeri* is represented by an abundance of very good specimens. Other important elements in the flora are: *Sphenophyllum saxifragaefolioides* Leyh., *S. geigense* Lutz, *Neurocardiopteris*, *Cardiopteris*, *Rhacopteris lindsaeformis* Bunb., *R. semicircularis* Lutz, *Archaeopteridium dawsoni* Stur, *Sphenopteridium*, *Calathiops* and different species of *Rhodea*.

It is interesting to note that Lacey (1952 : 375,376) mentions two specimens from the Lower Carboniferous of Wales both of which may well belong to *Lepidodendropsis*. One of the specimens is from Craig Quarry, nr. Denbigh. The other (p. 375) comes from the Dyserth locality and was originally named *Lepidophloios* cf. *laricinus* Sternberg.

Dubertret (1933 : 288) has recorded lepidodendroid remains associated with a Tournaisian fauna in the Jebel Abd el Aziz, North-east Syria, and Mr. W. N. Edwards informs me that there are some fragments probably referable to *Lepidodendropsis* in the British Museum (Natural History) collected by W. A. Macfadyen from the Wadi Gharra, Jebel Abd el Aziz.

Another flora which may be compared with that of the Peruvian Lower Carboniferous was described from Egypt (Jongmans & Koopmans, 1940). It was collected from samples of cores from wells in Rhas Gharib. The flora contains *Lepidodendropsis fenestrata* J. & K., *Sphenopteris whitei* (Berry)—originally named *Rhodea* cf. *hochstetteri*; the new determination, not yet published, is based on better specimens collected in 1946—and *Cyclostigma aegyptiaca* J. & K.

In the same paper some specimens from Wadi Um Shebba, Sinai, were figured, which may also be compared with, and probably belong to *Lepidodendropsis* (*Lepi-*

dodendropsis sinaica J. & K. including two specimens of *Lepidodendron mosaicum* Salter figured by Seward, 1932, pl. 21, fig. 4, and pl. 22, fig. 9). In connection with the Carboniferous of Egypt it is interesting that *Porodendron* sp. described by Gothan (1933) from the Oasis di Cufra, may also belong to *Lepidodendropsis*.

An important contribution to the *Lepidodendropsis* flora of North Africa was published by Boureau (1954). He records the occurrence of *Rhacopteris ovata* and *R. circularis* in the Lower Carboniferous (? Dinantien) of Aïr, near Tafadeck, Central Sahara. Although *Lepidodendropsis* itself was not found at this locality, it is very probable that the horizon is that of the *Lepidodendropsis* flora, for according to a young French geologist whom I met in Algeria, he had collected *Lepidodendropsis* from the Lowest Carboniferous of the Sahara. I have not yet, however, seen the specimen which he promised to send to me for examination.

A plant which certainly belongs to *Lepidodendropsis* is *Sigillaria fezzanensis* Chiarugi (1948). This specimen is much like *Lepidodendropsis vandergrachti* J., G. & D. from the American Pocono and probably belongs to this species. It has nothing to do with *Sigillaria* and certainly not with *S. brardi* Bgt. with which it is compared by Chiarugi. On the strength of this comparison Chiarugi states that the locality belongs to an elevated part of the Carboniferous. In my opinion it belongs to the Lower Carboniferous or Upper Devonian in agreement with the marine fossils, which according to Borghi (1939) indicate a transition between the Mississippian and the Upper Devonian.

Chiarugi (1948 : 81) compares his material with Fritel's *Archaeosigillaria vanuxemi* Goepp. (1925, pl. 3, figs. 1–5). These specimens have leaf-cushions which are very approximate. However, fig. 3, upper part, and fig. 5 show clearly that the space between the individual leaf-cushions can become much larger. It is not clear from the figures whether there is a true leaf-scar, as in *Archaeosigillaria*, or not. A comparison of *Archaeosigillaria* and *Lepidosigillaria* with *Lepidodendropsis* can only be made by an examination of the original specimens.

Another figure in Fritel's paper with which comparison is possible is his *Lepidodendron* cf. *volkmannianum* (pl. 3, fig. 6*b*). This specimen was found at the same locality as his *Archaeosigillaria*.

Carpentier (1930) described a small flora from the Lower Carboniferous of Morocco. His *Lepidodendron ?* aff. *corrugatum* (pl. 1, fig. 3), Epi de Calamariée ? (pl. 2, fig. 3) and *Lepidodendron veltheimi* (pl. 4, figs. 1–3) most probably belong to *Lepidodendropsis*. It may even be that his *Arctodendron* (pl. 5, figs. 2, 2 bis) is an old stem of *Lepidodendropsis*. It is very curious, however, that at this locality, some very poorly preserved specimens were collected which simulate impressions of *Sigillaria*.

Lepidodendropsis hirmeri has also been collected by Meléndez and myself (1950) from the Lower Carboniferous of Valdeinfierno, Spain. Here it occurs at the same locality, but not exactly in the same place, with a flora containing *Asterocalamites scrobiculatus* Schl., *Stigmaria stellata* Goepp., *Sphenophyllum saxifragaefolioides* Leyh, *S. geigense* Lutz, *Rhodea* cf. *stachei* Stur, *R.* cf. *moravica* Ett., *Triphyllopteris* cf. *minor* J. & G., *T. collombiana* (Sch.), and *Calathiops* cf. *plauensis* Gothan.

This flora very much resembles that of Geigen, near Hof, and both may be compared with the floras of the Pocono, of Peru and of Egypt.

In the Donetz Basin the *Lepidodendropsis* flora is said to occur in the Upper Devonian. Zalessky (1931) described *Heleniella theodori* and compared it with some species of *Sigillaria* (*S. youngiana* Kidston, *S. tschirkovaeana* Zal., and *S. canobiana* Kidston) which show undulated ribs. However, an examination of well-preserved material collected by Zalessky and myself (1939) proved that they have nothing to do with *Sigillaria*. There are no ribs, but *Lepidodendron*-like leaf-cushions. The leaf-trace is never visible. These plants are identical with *Lepidodendropsis hirmeri* Lutz. Lutz compared *Lepidodendropsis* with *Helenia*, but the specimens of this latter genus, which occurs with *Heleniella*, are for the most part badly preserved. Undoubtedly most of the species of *Helenia* described by Zalessky (1931), especially *H. similis* and *H. bella*, belong to *Lepidodendropsis*. The same may be true for the specimens he calls *Lepidodendron stylicum*, but most of these are very intensively decorticated.

Zalessky (1930) described a new genus, *Micheevia*, from the Lower Carboniferous of the Ural mountains. Some of the species are indeterminable but *M. rimnensis*, *M. pulchella* and *M. uralica* certainly belong to *Lepidodendropsis*. M. *uralica* can be compared with *L. vandergrachti* from the Pocono, and *M. pulchella* with *L. hirmeri*.

In the same paper he figures *Helenia inopinata* which also belongs to *Lepidodendropsis*. The same may be said for his *Lepidodendron glincanum* (pl. 2, figs. 3, 4), but the specimens, some of which show their internal structure, are too decorticated to be certain. Possibly *Lepidodendron caracubense* Zalessky (1921) ought to be included in *Lepidodendropsis* but this is not certain.

It is probable that the specimen described by Schmalhausen (1883) as *Lepidodendron glincanum* Eichw. from the Egorshino region, together with those identified by Mägdefrau (1936, pl. 10, figs. 6–8) as *Heleniella theodori* from the Upper Devonian in the Thüringer Wald, and Gilkinet's *Lepidodendron nothum* (1922, pl. 13, fig. 76), all belong to *Lepidodendropsis*.

Gothan & Zimmermann (1937) described lepidodendroid remains from the Upper Devonian of Bögendorf-Libichau near Waldenburg. Several of their figures are very much like *Lepidodendropsis* but in most cases the specimens are too incomplete or too badly preserved to be certain. The small stems (pl. 24, figs. 1–4) and the specimens ascribed to *Protolepidodendropsis frickei* G. & Z. (pl. 24, figs. 6*a*, *b* ; pl.25, figs. 1, 1*a*, ? 7) almost certainly belong to *Lepidodendropsis*. In my opinion there is no reason for the creation of a new genus for these stems. Whether they are specifically identical with any of the species described in *Lepidodendropsis* is another question. However, there is a resemblance to *L. hirmeri* Lutz. Kräusel & Weyland (1949 : 136) also state that this genus is practically indistinguishable from *Lepidodendropsis*.

Gothan & Zimmermann (1937, pl. 22, figs. 1–4) described and figured a new species of *Sublepidodendron* (*S. antecedens*) from the Upper Devonian of Oberkunzendorf. Kräusel & Weyland (1949 : 146) state that it can be compared with *Lepidodendropsis*. It very probably belongs to this genus.

Hoeg (1942) described a new species of *Protolepidodendropsis* (*P. pulchra* Hoeg) from the Upper Devonian of Mimerdalen, Spitsbergen. He compares it with *Heleniella theodori* Zal. from the Donetz Basin, with *Protolepidodendron*, and with

Protolepidodendropsis frickei. Most of the specimens figured by Hoeg in his pls. 54 and 55 cannot be separated from *Lepidodendropsis*.

Another group of lepidodendroid plants with which Hoeg compares his new species is *Sublepidodendron*, especially *S. subfallax* Nath. and *S. nordenskioldi* Nathorst (1920). Several of Nathorst's figures resemble *Lepidodendropsis* at first sight, but the structure and position of the leaf-cushions in *Sublepidodendron* do not permit one to unite them with *Lepidodendropsis*. The most typical species described by Nathorst from Spitsbergen, *Sublepidodendron mirabile*, *S. fallax*, *S. subfallax* and *S. nordenskioldi*, are considered by Gothan (1933) to be synonymous, and he includes them all in one species *Sublepidodendron mirabile* Nathorst. Gothan, however, does not use this generic name and retains the species under *Lepidodendron*. In my opinion and in accordance with Nathorst (1920), Hirmer (1927) and Gothan & Zimmermann (1937) it is necessary to separate them from *Lepidodendron*. Gothan also unites *Lepidodendron leeianum* G. & S. with *L. mirabile*, but Sze (1936) does not agree and considers the former to be a distinct species of *Sublepidodendron*.

Possibly *Lepidodendron calamitoides* Nathorst (1920, pl. 5, figs. 1–8, ? 9) also belongs to this group. The relationship of *L. kidstoni* Nathorst (1920, pl. 3, figs. 1*a*, 2–7) is more doubtful. It may be that such specimens are in some respects already transitional to the true Lepidodendra. There are several species of *Lepidodendron* in the Namurian and in the upper part of the Mississippian, which resemble *Sublepidodendron* in many characters, but their leaf-cushions, and especially their true leaf-scars, are lepidodendroid. Such species include *L. kidstoni* Nath. (which can be compared with *Sublepidodendron*), *L. robertii* Nath., *L. acuminatum* Goepp., *L. spetsbergense* Nath., *L. osbornei* Walkom and perhaps *L. volkmannianum*.

Carpentier (1932 : 33) compared the previously described *Lepidodendron corrugatum* Dawson (Carpentier, 1925, pl. 13, figs. 6–8) from the Tournaisian of Bois Gamats, near Laval (Mayenne), with *Heleniella theodori* Zal. So far as one can judge from his figures, especially that of 1932, he is quite right in this comparison, and in my opinion they are at least distantly related to *Lepidodendropsis hirmeri*. Zalessky (in litt.) objected to Carpentier's conclusions and supposed that the French specimens most probably belonged to a new type. His objections, however, were based on incomplete knowledge of his genus *Heleniella*. A revision of this genus has since been made, based on new material collected by Zalessky and myself.

Lepidodendropsis is also known from some other localities in Asia. Zalessky (1937) figures a small poorly preserved specimen from the River Niaysse, 4 km. from the River Mania-Niaysse, which he names *Heleniella theodori*. It may belong to *Lepidodendropsis* but it is impossible to be certain. From the same locality he describes *Ularia ovalis* Zal. which he considers to be a rhizome of a Lepidophyte (Zalessky, 1937 : 10, pl. 9, fig. 1). It is possible that this also is a fragment of *Lepidodendropsis*. He compares the specimen with *Stigmaria exigua* Dawson (1871, pl. 3, fig. 30, 30*a*) but Dawson's specimen does not allow further determination.

As already mentioned Sze (1936) does not agree with Gothan's identification of *Lepidodendron leeianum* Gothan & Sze with *Sublepidodendron mirabile* Nath. In the same paper Sze describes a number of specimens from the Chinese province of

Kiangsu as *Lepidodendron* aff. *leeianum* Goth. & Sze (? n. sp.) which very much resemble *Lepidodendropsis*. He states that the leaf-scars are not very distinct. In the figures, especially pl. 2, fig. 2, the leaf-cushions are very similar to those of *Lepidodendropsis*, and no leaf-scar is present.

Protolepidodendron (?) *arborescens* Sze (1936*a*) almost certainly belongs to *Lepidodendropsis*. It has nothing to do with *Protolepidodendron*, which is characterized by leaves divided in their upper parts. Sze (pl. 2, fig. 8) figures a divided leaf, but there is no proof that it belongs to this species. He compares the species with *P. scharyanum* Krejci (Halle 1936, pls. 2, 3; text-fig. 1) from Yunnan, which, apart from the division of the leaves, is also much like *Lepidodendropsis*. I should not hesitate, if such leaves were absent, to unite it with this genus.

Halle's material shows that at least some of the specimens named *Protolepidodendron* are distinguishable from *Lepidodendropsis* by the divided leaves only. Whether the presence or absence of the division in these leaves is sufficient ground for a generic separation (cf. Kräusel & Weyland 1949 : 136) is, in my opinion, rather doubtful. Sze also doubts whether such specimens as those figured by Halle belong to *Protolepidodendron*.

Walkom (1928) described two new species of *Protolepidodendron* (*P. lineare* and *P. yalwalense*) from Yalwal, New South Wales. He compared the first with *P. primaevum* (White) which has since been named *Lepidosigillaria* (Kräusel & Weyland, 1949 : 148), and *P. yalwalense* with *Lepidodendron karakubense* Schmalh. which is possibly *Lepidodendropsis*. Both the plants used for comparison by Walkom have been recorded from beds considered to be Upper Devonian, and for this reason Walkom also includes the Yalwal beds in the Upper Devonian, although they are considered to be Carboniferous by Clarke and other authors.

At a number of localities the flora, as far as it is known, does not contain *Lepidodendropsis*, but *Rhacopteris* of the *ovata* group only. Such is the case in Australia (Feistmantel 1890), some parts of South America, and also in Spiti, India, the flora of which has been described by Gothan & Sahni (1937).

It is clear that the *Lepidodendropsis* (*Rhacopteris*) flora, or at least related floras, are found all over the world, and this is very important for the stratigraphy of the Lower Carboniferous and for comparison with the Upper Devonian. It is interesting to note that such plants, especially *Lepidodendropsis*, also occur in different localities which are considered as Upper Devonian. This fact is not surprising, since in many cases it is almost impossible to separate what is considered to be Upper Devonian from the Lower Carboniferous. In some cases these so-called Upper Devonian floras are typical *Lepidodendropsis* floras, as in the Donetz Basin.

It is possible that the *Lepidodendropsis-Rhacopteris* floras represent a transition between the *Archaeopteris-Cyclostigma* floras of the Devonian and the floras of the lower part of the Mississippian.

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EXPLANATION OF PLATES

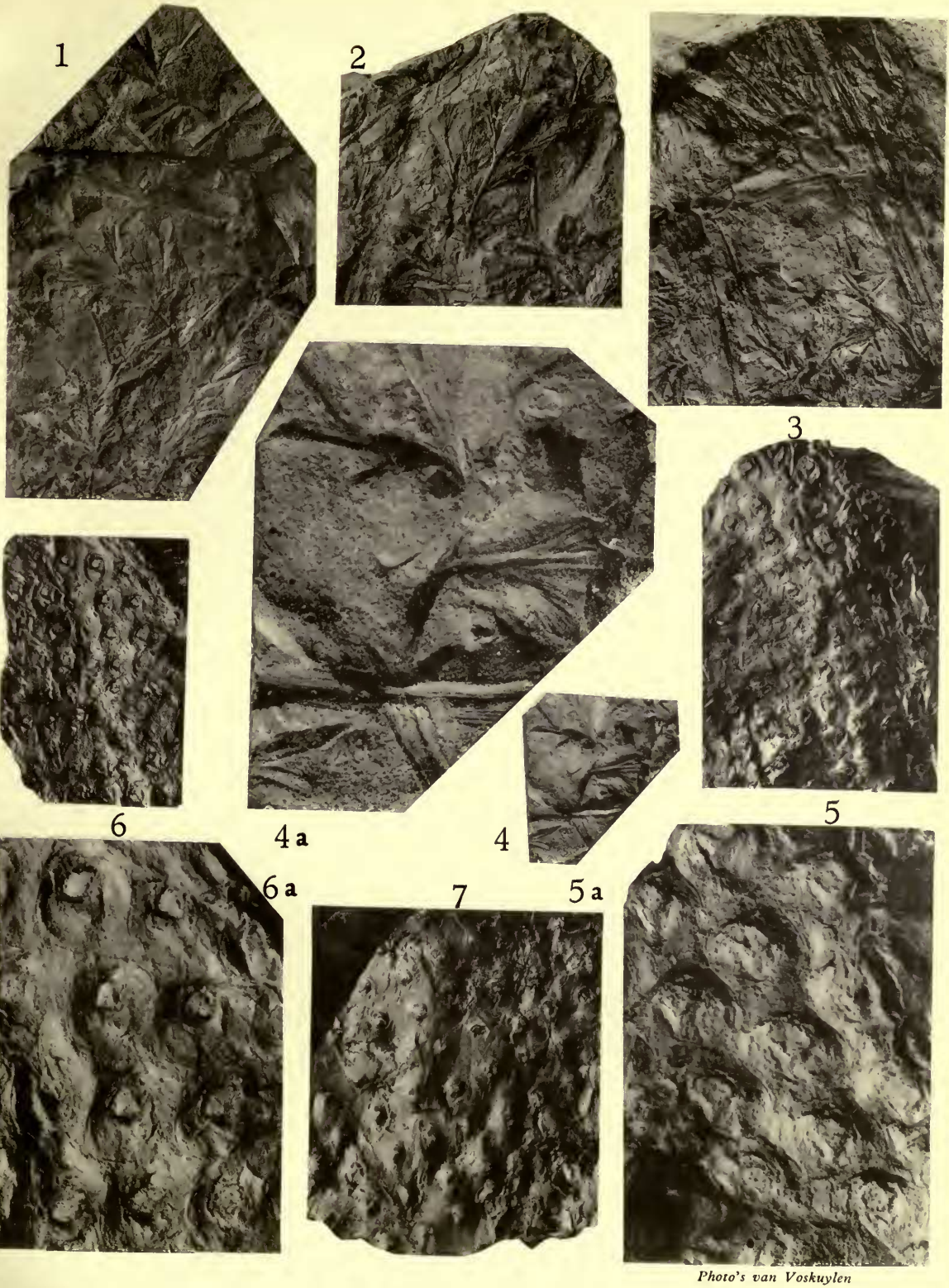
The specimens figured in Pl. 17–20 are in the Department of Geology, British Museum (Natural History). Those figured in Pls. 21–26 belong to the Geologisch Bureau, Heerlen. All the photographs were taken by Mr. Van Voskuijlen, Geologisch Bureau, Heerlen.

Unless otherwise stated all the figures are natural size.

PLATE 17

Sphenopteris whitei (Berry) and *Cyclostigma pacifica* (Steinmann).
Lower Carboniferous (Mississippian); Paracas, Peru.

FIG. 1. *Sphenopteris whitei* (Berry). V.25936.
FIG. 2. *Sphenopteris whitei* (Berry). Counterpart of fig. 1. V.25936*a*.
FIG. 3. *Sphenopteris whitei* (Berry). V.25942.
FIG. 4. *Sphenopteris whitei* (Berry). Part of counterpart of fig. 1. V.25936*b*.
FIG. 4*a* Enlargement of fig. 4, × 3.
FIG. 5. *Cyclostigma pacifica* (Steinmann). V.25925.
FIG. 5*a* Enlargement of fig. 5, × 3.
FIG. 6. *Cyclostigma pacifica* (Steinmann). V.25925*a*.
FIG. 6*a* Enlargement of fig. 6, × 3.
FIG. 7. *Cyclostigma pacifica* (Steinmann). V.25928.



Photo's van Voskuylen

SPHENOPTERIS, CYCLOSTIGMA

PLATE 18

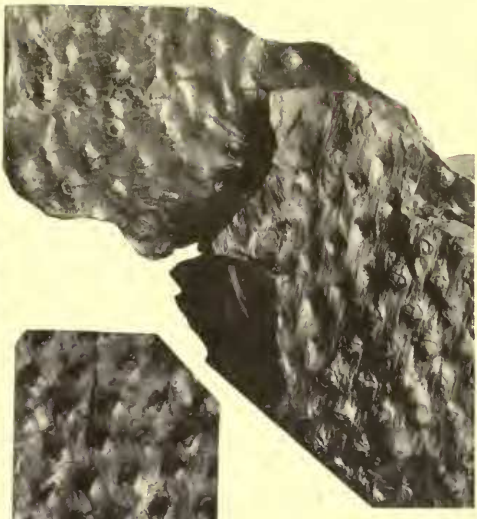
Cyclostigma pacifica (Steinmann).

Lower Carboniferous (Mississippian); Paracas, Peru.

FIG. 8. *Cyclostigma pacifica* (Steinmann). V.25920.
FIG. 8*a* Enlargement of fig. 8, × 3.
FIG. 9. *Cyclostigma pacifica* (Steinmann). V.25918.
FIG. 9*a* Enlargement of fig. 9, × 3.
FIG. 10. *Cyclostigma pacifica* (Steinmann). V.25918*a*.
FIG. 10*a* Enlargement of fig. 10, × 3.

8 a

8



9

10

10 a

9 a

CYCLOSTIGMA

PLATE 19

Cyclostigma pacifica (Steinmann).

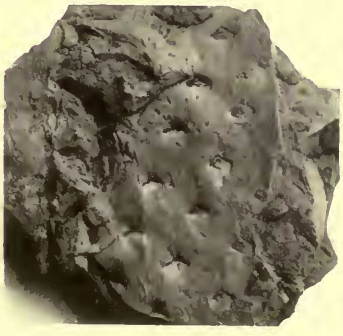
Lower Carboniferous (Mississippian); Paracas, Peru.

FIG. 11. *Cyclostigma pacifica* (Steinmann). V.25917.
FIG. 12. *Cyclostigma pacifica* var. *decorata* Jongmans. V.25948.
FIG. 12*a* Enlargement of fig. 12, × 3.
FIG. 13. *Cyclostigma pacifica* (Steinmann). V.25933.
FIG. 14. *Cyclostigma pacifica* var. *decorata* Jongmans. V.25919.
FIG. 14*a* Enlargement of fig. 14, × 3.
FIG. $14b_1$ *Cyclostigma pacifica* (Steinmann). V.25916. Enlargements (figs. $14b_2$ and $14b_3$) on Pl. 20.

11

12

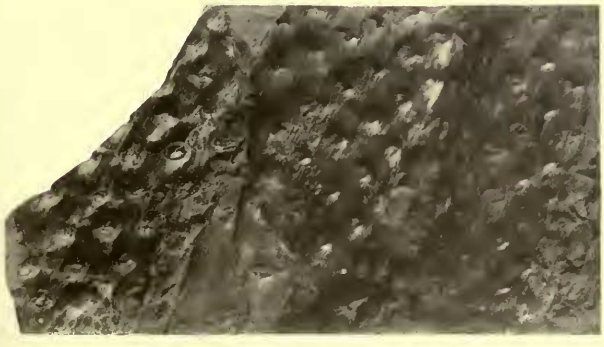
12 a



13

14

14 a



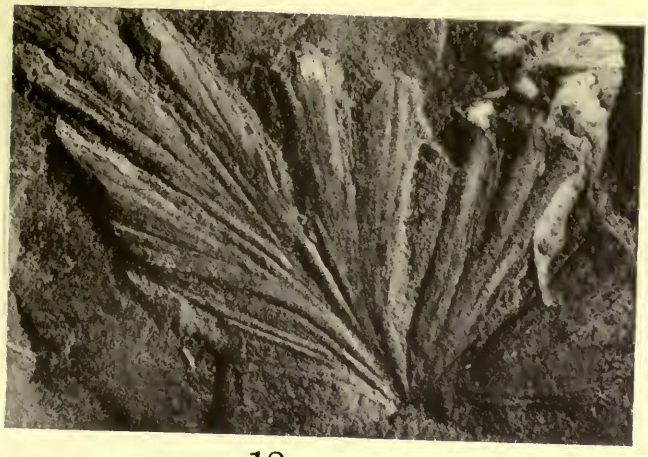
14 b 1

PLATE 20

Cyclostigma pacifica (Steinmann), *Lepidodendropsis peruviana* (Gothan), ? *Lepidodendropsis lissoni* (Steinmann), *Lepidodendropsis* sp., *Rhacopteris* cf. *cuneata* (Walkom) and *Rhacopteris ovata* (McCoy).

Lower Carboniferous (Mississippian); Paracas, Peru.

FIG. 14b_2 *Cyclostigma pacifica* (Steinmann). Enlargement of fig. 14b_1, × 3.
FIG. 14b_3 *Cyclostigma pacifica* (Steinmann). × 3.
FIG. 15. *Lepidodendropsis peruviana* (Gothan). V.25911.
FIG. 16. ? *Lepidodendropsis* (*Lepidodendron*) *lissoni* (Steinmann). V.25932.
FIG. 17. ? *Lepidodendropsis* sp. V.25915.
FIG. 18. *Rhacopteris* cf. *cuneata* (Walkom). V.25948*a*.
FIG. 18*a* *Rhacopteris* cf. *cuneata* (Walkom) and *Rhacopteris ovata* (McCoy). The specimen is on the reverse side of that shown in fig. 12.
FIG. 18a_1 *Rhacopteris* cf. *cuneata* (Walkom). Enlargement of fig. 18*a*, × 3.



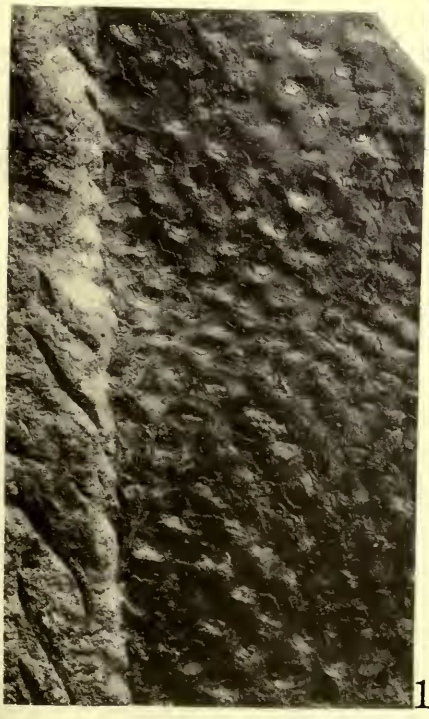
18 a 1

16

18 a

14 b 2

14 b 3



17

18

15

CYCLOSTIGMA, LEPIDODENDROPSIS, RHACOPTERIS

PLATE 21

Lepidodendropsis de voogdi n. sp.

Lower Carboniferous (Mississippian) ; Carhuamayo, Peru.

FIG. 19. *Lepidodendropsis de voogdi* Jongmans. Photo 8414.
FIG. 20. *Lepidodendropsis de voogdi* Jongmans. Traces of the sporangia are visible on the left of the figure. Photo 8416.
FIG. 21. *Lepidodendropsis de voogdi* Jongmans. Photo 8444.
FIG. 21*a* Enlargement of fig. 21, × 3.
FIG. 22. *Lepidodendropsis de voogdi* Jongmans, showing sporangia containing megaspores. Photo 8413.
FIG. 22*a* Enlargement of fig. 22, × 3.
FIG. 23. *Lepidodendropsis de voogdi* Jongmans. Photo 8413*a*.

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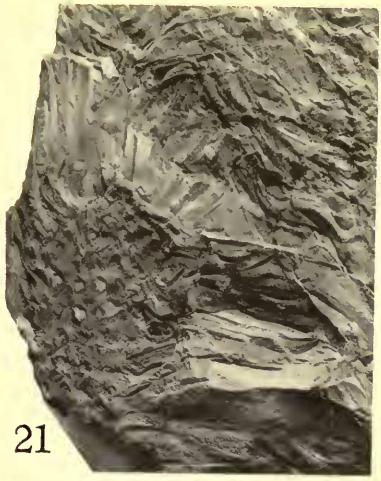

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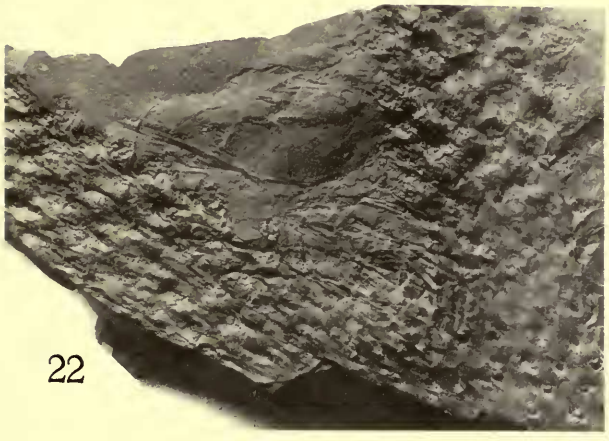

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21 a

22 a

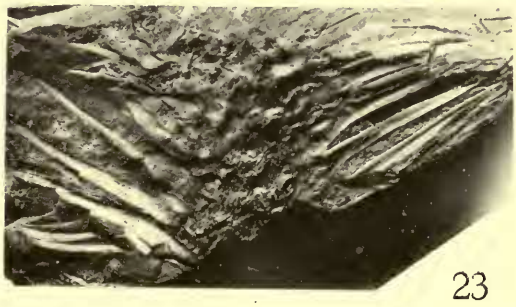

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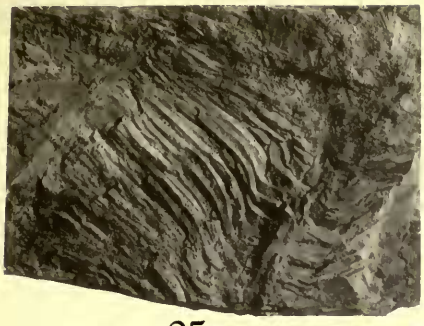
PLATE 22

Lepidodendropsis de voogdi n. sp., and *Lepidodendropsis steinmanni* n. sp.
Lower Carboniferous (Mississippian) ; Carhuamayo, Peru.

FIG. 24. *Lepidodendropsis de voogdi* Jongmans. Photo 8445.
FIG. 25. *Lepidodendropsis de voogdi* Jongmans. Photo 8449.
FIG. 26. *Lepidodendropsis de voogdi* Jongmans. Photo 8443.
FIG. 27. *Lepidodendropsis de voogdi* Jongmans. Photo 8448.
FIG. 28*a* *Lepidodendropsis steinmanni* Jongmans, showing habit of the stem with leaves. Photo 8415.
FIGS. 28*d*, 28*da*. Pith-cast, belonging to specimens in figs. 28*a* and 28*b* (Pl. 23). Photo 8450. Fig. 28*da*, × 3.



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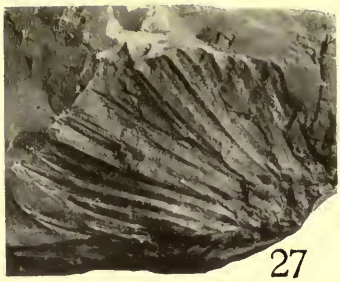

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24

28 a

28 d

28 da

PLATE 23

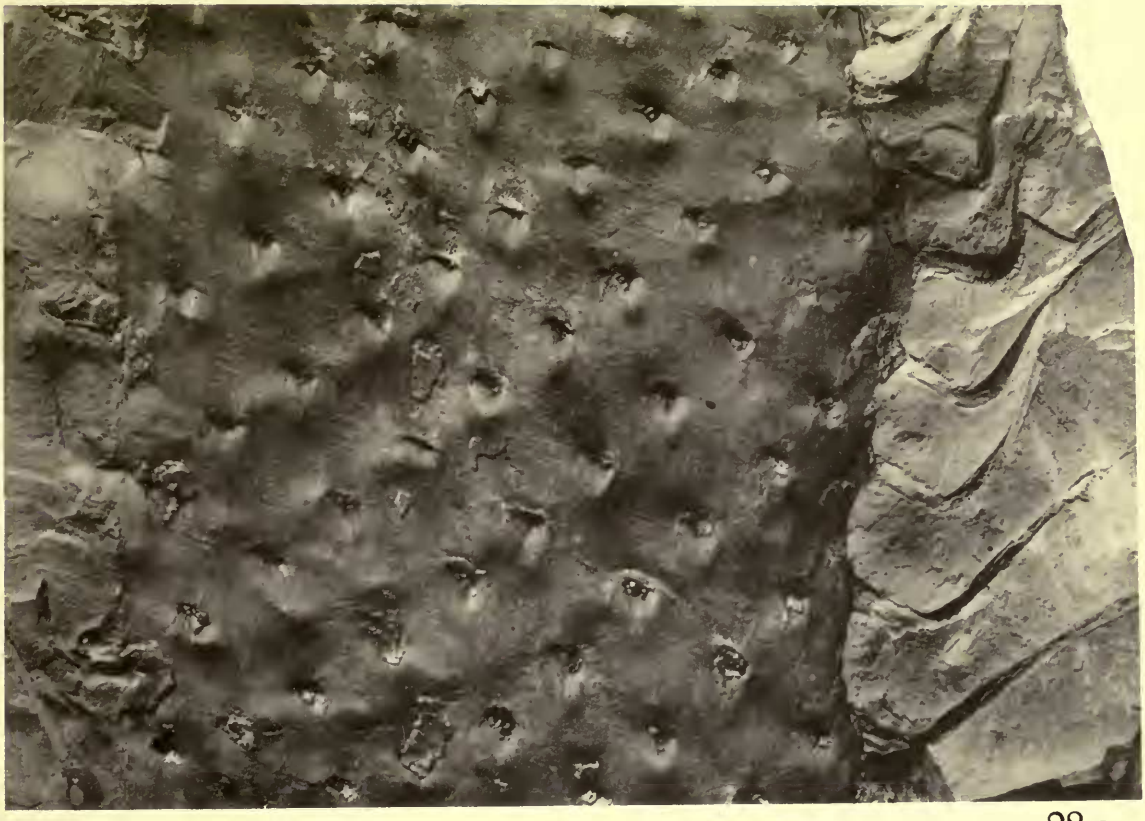
Lepidodendropsis steinmanni n. sp. and *Cyclostigma* cf. *pacifica* (Steinmann) var. Lower Carboniferous (Mississippian); Carhuamayo, Peru.

FIG. 28*b* *Lepidodendropsis steinmanni* Jongmans. Counterpart of fig. 28*a* with better preserved leaves. Photo 8415.

FIG. 28*c* Enlargement of part of Fig. 28*b* showing the leaves, × 3. Photo 8415.

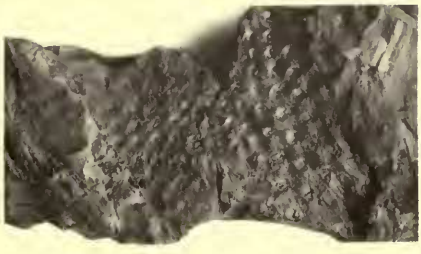
FIG. 29*a* *Cyclostigma* cf. *pacifica* (Steinmann) var. Upper surface of stem. Photo 8451.

FIG. 29*aa* Enlargement of fig. 29*a*, × 3.

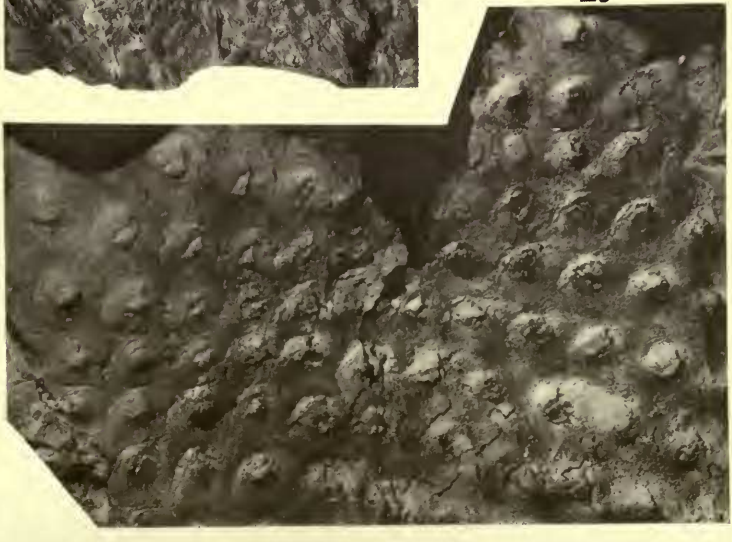


28 c

28 b



29 a



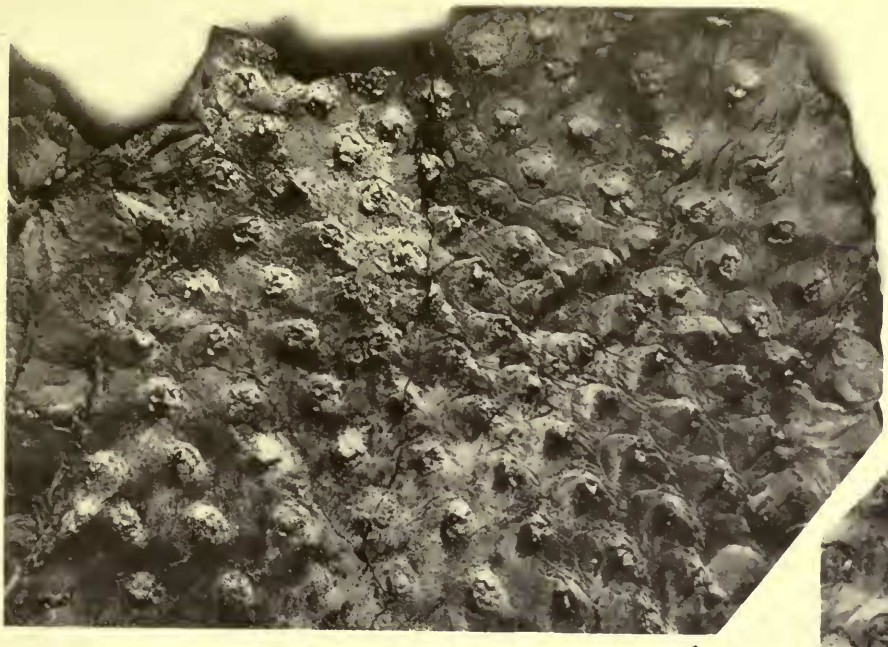
29 aa

LEPIDODENDROPSIS, CYCLOSTIGMA

PLATE 24

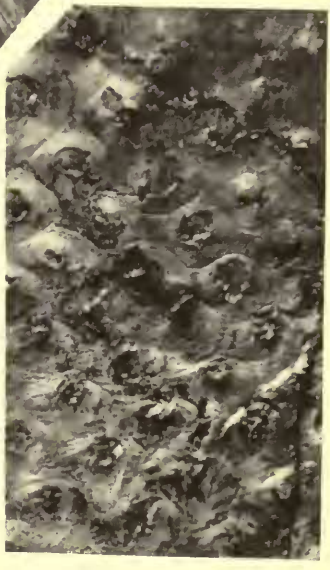
Cyclostigma pacifica (Steinmann) and *Lepidodendropsis* cf. *steinmanni* Jongmans. Lower Carboniferous (Mississippian); Carhuamayo, Peru.

FIG. 29*b* *Cyclostigma* cf. *pacifica* (Steinmann) var. Lower surface of stem. Photo 8451.
FIG. 29*ba* Enlargement of fig. 29*b*, × 3.
FIG. 29*c* *Cyclostigma* cf. *pacifica* (Steinmann) var. Pith-cast belonging to figs. 29*a* and 29*b*. Photo 8451.
FIG. 29*ca* Enlargement of fig. 29*c*, × 3.
FIG. 30. *Cyclostigma pacifica* (Steinmann). With leaves attached. Photo 8532.
FIG. 30*a* Enlargement of fig. 30, × 3.
FIG. 31. *Lepidodendropsis* cf. *steinmanni* Jongmans. Photo 8447.

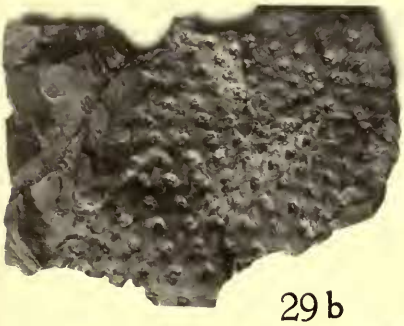


29 ba

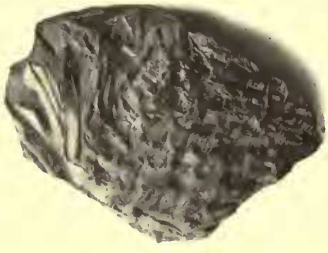
29 c



29 ca



29 b



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30 a

31

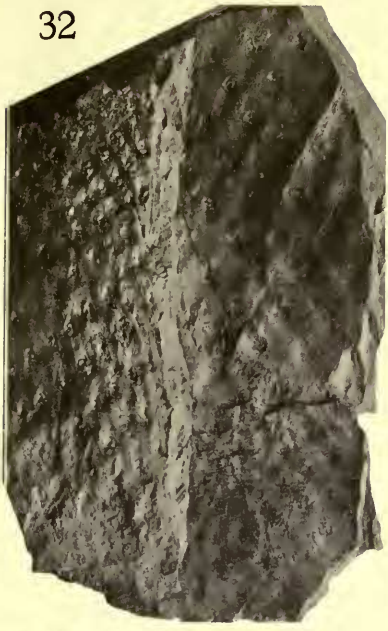
CYCLOSTIGMA, LEPIDODENDROPSIS

PLATE 25

Lepidodendropsis cf. *de voogdi* Jongmans, *Rhacopteris ovata* (McCoy) and *Rhacopteris* cf. *circularis* Walton.

Lower Carboniferous (Mississippian) ; Carhuamayo, Peru.

FIG. 32. ? *Lepidodendropsis* cf. *de voogdi* Jongmans. Photo 8446.
FIG. 33. *Rhacopteris ovata* (McCoy). Photo 8456*d*.
FIG. 34. *Rhacopteris ovata* (McCoy). Photo 8456*b*.
FIG. 35. *Rhacopteris ovata* (McCoy). Photo 8452.
FIG. 36. *Rhacopteris ovata* (McCoy). Photo 8454.
FIG. 37. *Rhacopteris ovata* (McCoy). Photo 8453.
FIG. 38. *Rhacopteris* cf. *circularis* Walton. Photo 8456*a*.



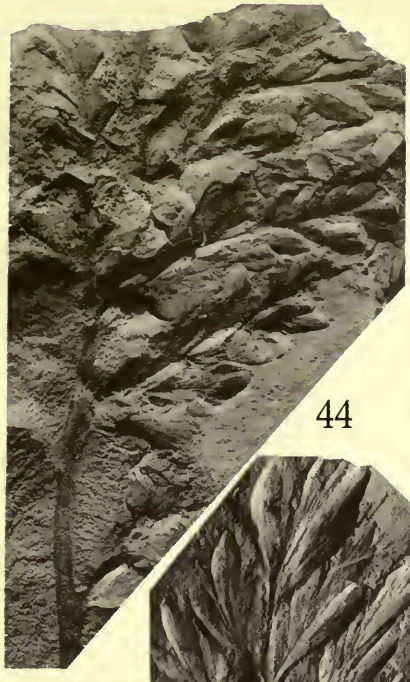
LEPIDODENDROPSIS, RHACOPTERIS

PLATE 26

Rhacopteris cf. *circularis* Walton, *Rhacopteris ovata* (McCoy), *Triphyllopteris collombiana* (Sch.), *Triphyllopteris lescuriana* (Meek) and ? *Triphyllopteris peruviana* Jongmans.

Lower Carboniferous (Mississippian); Carhuamayo, Peru.

FIG. 39. *Rhacopteris* cf. *circularis* Walton. Photo 8456*c*.
FIG. 40. *Triphyllopteris collombiana* (Sch.) Photo 8455.
FIG. 41. *Triphyllopteris collombiana* (Sch.) Photo 8455*a*.
FIG. 42. *Triphyllopteris collombiana* (Sch.) Photo 8455*b*.
FIG. 43. *Triphyllopteris lescuriana* (Meek). Photo 8458*a*.
FIG. 44. *Triphyllopteris lescuriana* (Meek). Photo 8458*b*.
FIG. 45. *Triphyllopteris lescuriana* (Meek) and *Rhacopteris ovata* (McCoy). Photo 8458.
FIG. 46. ? *Triphyllopteris peruviana* Jongmans. Photo 8457.



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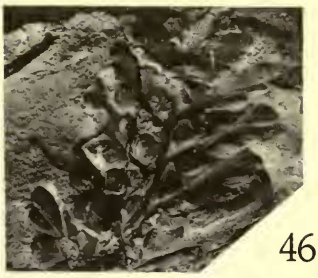

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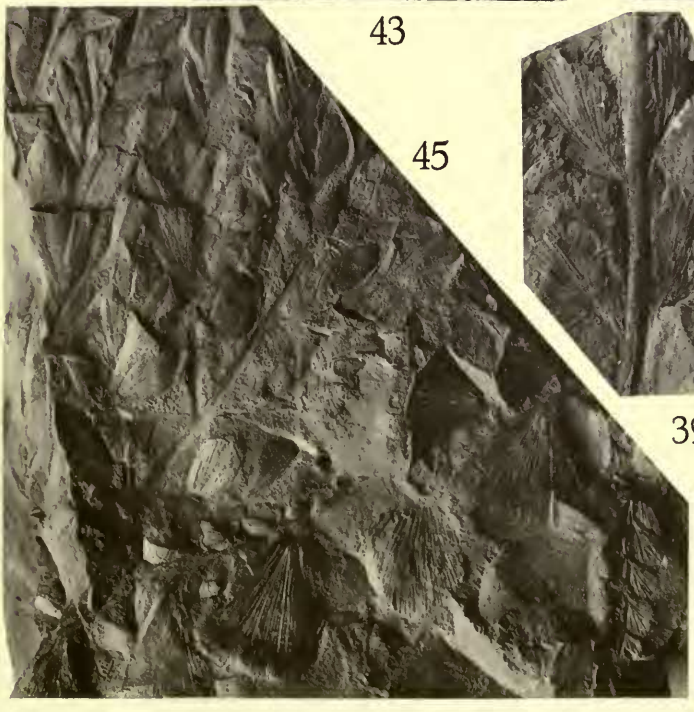

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RHACOPTERIS, TRIPHYLLOPTERIS